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HUMAN RELIABILITY STUDY, PHASE I

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An investigation has been performed to determine the reliability, validity, and completeness of published industrial safety data for the purpose of predicting personnel hazard resulting from human error. Technical papers, safety publications, and industrial data banks have been collected, reviewed, and assembled into a complete safety bibliography; those sources having direct impact on the present study have been collected into a smaller, annotated bibliography.

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SECTION 1.

SUMMARY

SUMMARY

An investigation has been performed to determine the reliability, validity, and completeness of published industrial safety data for the purpose of predicting disruption of equipment, property, launch schedule, or injury/death, resulting from human error. Technical papers, safety publications, and industrial safety data banks have been surveyed, reviewed, and assembled into a complete safety bibliography; those sources having direct impact on the present study have been collected into a smaller annotated bibliography for ease of review.

Two conclusions have emerged from the study effort. (1) Randomness of approach, differences in goals, and omission of critical factors frustrate the systematic evaluation of published safety information from a cause-effect orientation, limiting the results to a narrative assessment. (2) These very omissions indicate clearly the direction of future study, and offer promise of developing viable predictive methods.

In conjunction with the latter aspiration, several models of human performance applicable to complex industrial/military systems are reviewed, and a composite human reliability model is suggested for specific application to the Kennedy Space Center Support Operations environment. Parameters of the human as a decision maker and effector are combined with estimates of the several craft hazards involved at KSC as inputs to the model, leading to the development of an algorithm which may be run iteratively on a digital computer to achieve convergence. Applicable methods of programming are discussed.

SECTION 2.

PURPOSE, CONCLUSIONS, AND RECOMMENDATIONS

PURPOSE OF STUDY

The Human Reliability Study was undertaken to determine whether current information sources could yield data useful in the analysis and prevention of "Human Errors" which could impact launch operation schedules.

The term information source is inclusive in that both the technical literature and specific sources of safety data were examined. In addition to collecting, documenting, and organizing the information available, the study team probed other possible sources of data on potentially hazardous human error.

Procedure

The technical literature, information sources, and data gathering methods were analyzed and evaluated as measured against the program objective of obtaining useful quantitative information. Of main interest was the type of information available, statistical validity and reliability, reproducibility of results, and the ability of data and conclusions to be generalized to other areas. Literature was searched for relevancy and methodology explored when it was felt that this procedure would contribute to the overall study.

CONCLUSIONS

After evaluating the technical literature and the quantitative information sources, it was clear that retrospective studies could contribute less to the knowledge of man-machine system error than sources actively involved in the data-gathering process. The comparison and analysis of safety from one context to another is not easy; the many problems associated with gathering comprehensive data make it difficult to provide measurements of accidents and accident rates that give insights into the underlying causes of man-machine system failures.

The major conclusion of this Human Reliability Study is that, although useful information can be developed by current sources within the limitations imposed by present data-gathering techniques, a new system for gathering data should be developed. Because industrial accidents are symptoms of failures in a man-machine system--a failure reflects the inability of men or materials to meet the demands of the system--it follows that increased knowledge of decisions made within the man-machine system and of the hazards, efficiencies, capabilities, limitations, and the like, would tend to decrease the failure rate and contribute to overall safety. To this extent current data sources contribute limited amounts of information.

The technical literature contains many retrospective studies of industrial accidents. These studies use different analytical techniques, definitions, criteria, and sources of data. Insufficient hazard and exposure data provides another source of uncertainty and makes it impossible to combine or pool the results of these studies to get better data.

Prospective Studies

On the other hand, prospective studies can be designed to obtain the type of information necessary for pooling results in addition to obtaining those specific types of information useful in studying the problem of human reliability. This comment is particularly applicable to static sources involving the analysis of previous reports and those relying on files of information previously gathered (industrial safety commissions, insurance companies, hospitals, and the like).

A logical corollary to this conclusion is that modifications could be made to current sources which would provide more useful information to the safety researcher. By coordinating the type of information obtained from information sources, basic demographic and causal information could be obtained. Modifications to existing accident report forms and to reporting procedures would require the cooperation of the information source and of some coordinating agency. If incorporated within a human reliability data gathering system, these sources could aid in the identification and assessment of the overall human reliability problem.

RECOMMENDATIONS

The problem of the factors contributing to human errors is remarkably complex; however, the techniques of human factors engineering provide a methodology for incorporating them into the design, operation, and maintenance of man-machine systems. Human factors literature contains many examples of significant reductions in the number and types of "Human Errors" as the direct result of the application of human factors technology to specific design problems.

General Policy Recommendations: Frequently this study found the need for a team approach to human reliability research. Such a team should include psychologists, sociologists, physiologists, environmental engineers, design engineers, safety engineers and human factors engineers, as a nucleus and should draw on the consulting services of other specialists as required. Ideally, personnel selected for this type of research should be cross-trained and have experience in more than one of the above fields to facilitate technical interaction within the group.

Personnel selected for the data gathering program should be organizationally independent. They should have authority to investigate accidents but should not be attached to any organizational element which has either a vested interest in winning a safety contest, or determining eligibility for workman's compensation, or legal liability. All the above are worthwhile goals in their own right but are incompatible with the confidential exchange of information necessary for determining the true causes of human errors.

Specific Requirements: The specific requirements for the human reliability data gathering program must be defined before a definite program can be established. The recommended elements for the human reliability data gathering program are:

1. An independent in-depth accident investigation team.

2. Periodic human engineering audit of: facility, working environment, protective devices, job aids, tool design, selection and training, operational procedures.

3. Establish, supervise and conduct research projects.

4. Develop liaison with cooperative safety agencies.

SECTION 3.

TASKS ACCOMPLISHED FOR THE HUMAN RELIABILITY STUDY

TASKS ACCOMPLISHED FOR THE HUMAN RELIABILITY STUDY

Introduction

The primary objective of the Human Reliability Study Phase I was to perform a complete survey of the technical literature to evaluate previous work, and define the approach for quantitative study.

The ultimate objective of the Human Reliability Study is to define an approach for the development of a quantitative procedure for estimating the reliability of technician-level personnel in an operational situation. This procedure will extend the basic principles of reliability engineering to the human element. To assure flexibility of application to all pertinent industrial occupations will require a comprehensive approach to the problem. This procedure will probably encompass data from the fields of system engineering, operations analysis, human factors engineering, safety engineering, experimental psychology, and reliability engineering.

The literature search performed in Phase I directly supports this final objective. The literature search covered the widest range of topics in the fields named above. Throughout the literature search, emphasis was on the location and extraction of quantitative data relating to industrial safety/human error/human reliability. The specific data sought was accident rates, and contribution of human error to accident rate, for each specific industrial occupation.

The search of the technical literature was augmented by a survey of potential sources of quantitative industrial accident data. The objective of the survey was to locate industrial accident data banks which could support specific parametric studies of human reliability.

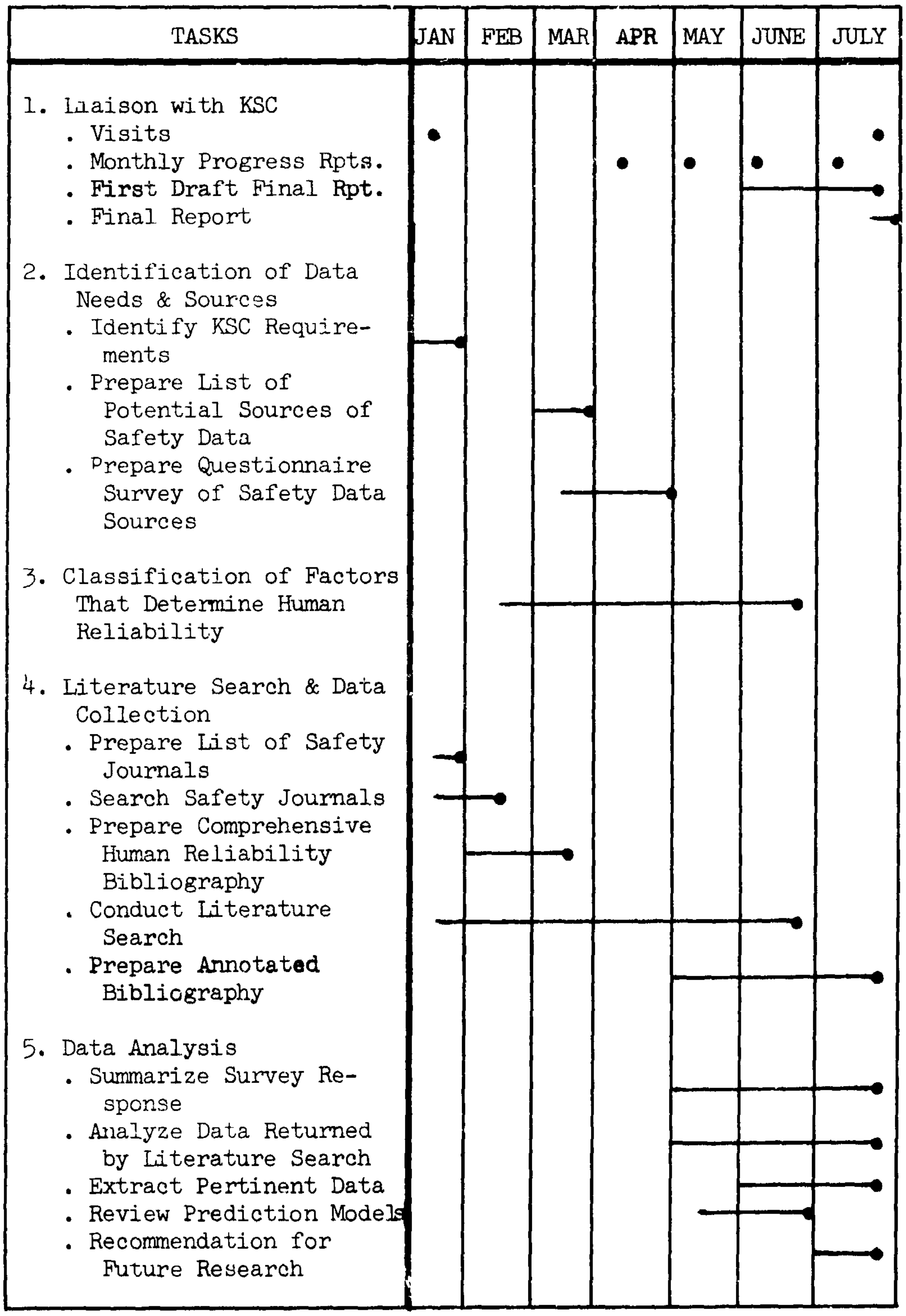
The development of a procedure for estimating the system reliability of technician-level personnel will enable public officials charged with the responsibility to plan, develop, and operate man/machine systems to evaluate alternate solutions in terms of their effect on the human error rate.

Time-Phased Task Schedule

Phase I of the Human Reliability Study was performed in accordance with the schedule and task descriptions presented in Hughes'Technical Proposal. For convenience in performing the study the five basic tasks were divided into meaningful subtasks. The completion of these tasks has provided the necessary groundwork for the Experimental Phase II Program.

The following time phased schedule indicates the flow of effort and coordination of tasks performed during the study. The five basic tasks performed during the study are:

HUMAN RELIABILITY STUDY SCHEDULE



Task 1. - Liaison with Kennedy Space Center:

Visits - Visits and periodic reports facilitated control, time phasing and periodic evaluation of progress.

As required by the contract, two visits were made to Kennedy Space Center. The first visit during the first week of the study for the purpose of coordination and the second visit during the seventh month for the purpose of presenting the first draft of the final report.

During the initial visit to KSC agreement was reached clarifying the definition of human error and the scope of the literature search involved.

Definition of Human Error - Human error is defined as failure to perform a prescribed act, (or the performance of a prohibited act), which could result in one or more of the following: (1) disruption of equipment, property, or scheduled operations: (2) launch delay or launch scrub; (3) injury; or (4) death.

Scope of the Literature Search - The literature search for quantitative data related to human errors in the performance of industrial craft jobs was limited to those labor categories supplied to Hughes by Kennedy Space Center. Human failure data related to performance of these industrial crafts in unusual environments and/or while wearing protective clothing are included in the literature search. Finally, the literature was searched for data related to the construction of prediction models for human failure data under the above conditions.

During the initial visit to Kennedy Space Center the Hughes' project engineer was given a tour of the facility by the KSC Contract Officer. Visits were made, operations observed, and conversations held with key personnel at the following locations:

Launch Pad
Vertical Assembly Building
High Pressure Gas Building
Chemical Cleaning and Laboratory

Arrangements were made with KSC personnel for descriptive material presenting an overview of the space center operations, list of occupational titles, copy of KSC Safety Procedures, and a few typical Support Operations Procedures.

Monthly Progress Reports: Four monthly progress reports were made, the first report was prepared 90 days after contract award.

Final Report: The first draft of the final report was mailed on 10 July for review by KSC personnel. During the second visit to KSC the final report was reviewed with KSC personnel and their comments incorporated in the final version.

Task 2. - Identification of Data Needs and Sources:

This task has two component parts; first the identification of Kennedy Space Center Support Operations Requirements and second the identification of potential sources of data which will meet those requirements.

A brief survey of Kennedy Space Center Support Operations was conducted during the two day initial visit to the space center. This was followed by an examination of the written material supplied by the space center. The combination of these efforts provided the basis for the identification of Support Operations Requirements.

A list of 275 potential sources of safety data was compiled from System Safety Handbook, National Safety Council Accident Prevention Manual, and the Lawyers Safety Desk Reference. A questionnaire survey was prepared for the purpose of ascertaining the type, availability, reliability, and relevance to the study, of safety data at each of these sources.

Task 3. - Classification of Factors that Determine the Reliability of Human Performance:

Only minor revisions and corrections were made to the classification of factors that determine human reliability which was presented in the proposal. The literature search did not contain any specific occupational data indicating the need for significant revisions in the classification scheme. Although no data was retrieved indicating quantitative values for specific factors broken down by occupation, there is extensive quantitative data relating to specific factors affecting the reliability of human performance in general. Since these data are readily available in many human factors handbooks there is no need to repeat them here.

(1) Instructions
- Procedures Required
- Verbal or Written Communications

(2) Task Characteristics
- Perceptual Discrimination Required
- Motor Discrimination Required
- Complexity (Information Load)
- Repetitiveness
- Continuity (Discrete Vs. Continuous)
- Feedback (Knowledge of Results)
- Human Engineering Factors Re: Man-Machine Interface Design

(3) Situational Characteristics
- Equipment Reliability Status
- Weather Factors - Visibility/Turbulence
- Other Contractor Personnel Supervisor & Team Partner Activities
- System Organization
- System Social Structure

(4) Psychological Stresses
- Task Speed
- Task Load
- High Jeopardy Risk
- Threat of Failure
- Monotonous Work
- Long, Uneventful Vigilance Periods
- Reinforcement Absent or Negative
- Sensory Deprivation
- Noise/Distracting Signals

(5) Physiological Stresses
- Fatigue
- Pain or Discomfort
- Hunger or Thirst
- Temperature Extremes
- G Force Extremes
  Weightlessness
  High G
- Atmospheric Pressure Extremes
- Oxygen Insufficiency
- Vibration
- Movement Constriction
- Lack of Physical Exercise

(6) Individual (Organismic) Factors
- Previous Training/Experience
- State of Current Practice or Skill
- Personality and Intelligence Variables
- Motivation
- Knowledge of Required Performance Standards
- Physical Condition
- AGE

(7) Individual Factors Risk Taking Behavior

CLASSIFICATION OF HUMAN
ERROR STRESS FACTORS

Task 4. - Literature Search and Data Collection:

The Literature Search and collection of data comprises the largest and most significant portion of the study. The literature search and collection of quantitative data were performed by graduate students from the Biotechnology departments of the University of California at Los Angeles and California State College at Long Beach. These graduate students worked directly under the supervision of the principal investigator and were supported in their use of library facilities by the Hughes-Fullerton research librarian. Weekly meetings were held during the first month of the literature search, biweekly thereafter.

Due to the relatively short time available to conduct the literature search it was necessary to perform tasks in parallel. A list of safety journals and publications was prepared from references in standard safety handbooks. While the graduate students were searching these journals for articles of interest sources of Human Reliability/Industrial Safety Bibliographies were contacted:

NASA STAR
Defense Documentation Center
California State Library
National Referral Center for Science and Technology
(Library of Congress)
National Safety Council Library

Simultaneously, the standard literature search indices were consulted and an inclusive bibliography was prepared. The following indices were consulted:

Readers Guide to Periodical Literature
Applied Science and Technology Index
Engineering Index
Psychological Abstracts
Humanities and Social Science Index
Business Index
Management Index
Human Factors Engineering Bibliographic Series

The resulting bibliography consisting of several thousand references was supplied to the graduate students for search. Finally, additional pertinent articles were added to the bibliography from bibliographies of searched articles. The results are tabulated in Appendix D.

The literature search was carried out at the Main Research Library University of California, Main Library, California State College at Long Beach, Los Angeles-Central Public Library; and Los Angeles County Central Library.

An annotated bibliography was prepared for those articles containing quantitative information or data relating to prediction models or performance factors; this is presented as Appendix C.

Task 5. - Data Analysis:

The data analysis task consisted of several subtasks. During the literature search a review was made of existing human reliability prediction models. The responses to the survey of potential sources of safety data were tabulated and the quantitative data extracted from the literature was reviewed, and gaps in the data were identified for inclusion in a Phase II research program.

Finally, an outline for an experimental program, and a specific plan for Phase II were prepared.

SECTION 4.

RESULTS OF THE HUMAN RELIABILITY STUDY

RESULTS OF THE LITERATURE SEARCH

Accident data has been collected by many agencies over the years. In addition to national agencies such as the National Health Survey, the U. S. Public Health Service, various state, local, public, and private agencies have contributed tabulated data relevant to determining accident and mortality rates. However, there are many problems associated with coordinating and using this information. While much of the information is incomplete, the major problems lie in the use of differing terms or definitions, varying statistical methods, non-standard forms, and the like.

Fatality Data: In a few cases where data has been compiled in compliance with official legislation, the information is almost complete. Mortality rates, for instance are available through the U. S. Vital Statistics data and the current estimates by the National Safety Council. But this data, while accurate as to the number of persons killed by age, sex, accident type, and industry, lacks many details describing the specific accident event.

In addition, most regular mortality data is based on information obtained from death certificates. In the past, these certificates have tended to be incomplete. The situation is further clouded by the variety of death certificates adopted on an individual basis by each of the states. In most cases this data does not yield information as to what, why, or how the accident occurred and would almost never specify any human performance factors that happened to be involved in the fatality.

Injury Data: Morbidity data (relating to non-fatal injuries) is even more incomplete. Deaths must be officially recorded, but non-fatal injuries, even those sustained in major accidents, may never be officially noted. A major problem associated with gathering information of this type is that even when it comes to the attention of a physician or hospital, no standard (or universal) procedure exists for recording pertinent data. More serious perhaps, is that there is no agreement on exactly what should be recorded.

The problem has been that, for most types of accidents, data is not available to make even the most general estimates of the true injury rate, unsafe act rate, and degree of exposure to hazard. When data is available it has been too generalized to enable the researcher to analyze specific causes or generate countermeasures.

By regulation, occupational accidents are reported to workmans compensation boards. The emphasis here is on determining eligibility and amount of compensation rather than accident cause and prevention. The reports of these proceedings provide a general background, but unfortunately this data is often in summary form. Analysis of data from the above sources is complicated because most states have their own laws, procedures, definitions, and forms with resulting lack of uniformity.

Unsafe Act Data: Data related to the commission of unsafe acts by industrial craft personnel is even more incomplete than data on non-fatal injuries. There are some accident data banks that record unsafe acts associated with accidents resulting in injury or death. However, the definitions and classifications used are so different as to make pooling of data difficult. During the literature search the only sources identified which were recording unsafe acts which did not cause lost time, injury, or death were the NASA Field Offices.

Where unsafe act data is recorded it indicates conclusively the significance of the human factor in the accident chain. For example the State of Pennsylvania reports unsafe acts as a factor in 94 percent of work injuries or fatalities recorded in 1968. Other sources indicate unsafe acts present in 80 to 95 percent of recorded industrial accidents.

Retrospective studies indicate that there is a significant interaction between the commission of unsafe acts, the quality of supervision, and the intensity of safety inspections.

RETROSPECTIVE STUDIES OF ACCIDENT AND INJURY DATA

In a comprehensive review of numerous research projects, some presented excellent information on the overall picture with respect to frequency, severity, and demographics.

Several studies had sufficient detail so that countermeasures were developed based on their data. However, most studies lacked this level of detail.

Few studies attempted to obtain exposure information - most studies were concerned with accident information related to overall frequency and severity rates, or to other specific goals.

Most studies provide reasonably accurate information within the limits of the information gathering technique used.

In many studies sampling errors could be calculated (for those studies). Because these studies cannot be combined into a group, error calculations cannot be made on an overall basis.

In general, the population covered by these various studies is sufficient to give information on both the overall picture and special details, if a method of combining data were developed.

The samples used in these studies represent specific cuts through the population. The representativeness of these samples and their utility in extrapolating results to specific population groups such as the Support Operations at Kennedy Space Center require limitations.

HUMAN RELIABILITY MODELS

Introduction: One of the main jobs of the natural sciences is to attempt to express the processes of Nature in mathematical form, thereby reducing great quantities of experimental data to simple relations between variables and permitting a unification of apparently diverse phenomena. Since most processes of Nature are exceedingly complicated, efforts to develop mathematical formulas that correspond exactly to physical reality are usually fruitless. In practice the major effort is concentrated upon the development of a mathematical model for salient features of a particular process. A good model will include the most important features of the process, will be mathematically simple (if possible), will involve a minimum of assumptions and will be fruitful for purposes of prediction and theoretical speculation.

The acid test for a model is empirical observation. Mathematically the model may be a thing of beauty, but if it does not correspond reasonably to physical observations, it must be relegated to that enormous bone yard of defunct hypotheses that the pragmatists have been filling since the dawn of scientific experimentation.

Occasionally several models may be found that account equally well for the observational data. In this case, and until the experimental results are sufficiently refined to favor one hypothesis over the others, the choice of model can be a matter of personal taste. Usually preference is given to the simplest of several alternative hypotheses.

We are concerned here with mathematical models for expressing the reliability of technician-level personnel performing operational tasks in accordance with approved procedures.

EPIDEMIOLOGICAL MODEL

Epidemiology originated from the study of disease epidemics: the path of communicable diseases among humans and the characteristics of the disease carrier, the victim, and the environment supporting the carrier and the victim are studied. A classic example of the epidemiological methods was by J. Snow who discovered from a geographical plot of cases that persons using one particular water supply had a death rate from cholera higher than that of persons using other water sources. Accidental injuries can be considered with the same techniques. If the characteristics of the "host" (the accident victim), of the "agent" (the injury deliverer), and of the supporting "environment" could be described in detail, more understanding could be achieved than by following the common technique of looking for only one or two features (or causes) of the accident antecedents. Essentially the accident is the result of a complex interaction between these three variables and cannot be "explained" by consideration of only one part of this triad.

McFarland, a proponent of the epidemiological method for accident research described it thus:

> The objective of the epidemiological method is to determine the laws and interrelated factors governing the occurrence of disease or other abnormalities of health in a specific population. In any community, various factors may be at work which give rise to disease or disability. An epidemiological approach thus involves the study of influences of many kinds, including the characteristics of the host of a variety of agents, and of the environment. This usually requires the collaboration of scientists from several fields or disciplines, and the team approach has been essential to many important advances. For example in the epidemic study of malaria, collaboration between the physician, the entomologist, the sanitary engineer, and other specialists was necessary to secure basic data and bring about control. In industry, such a collaborative approach might include, in addition to the industrial physician, the safety engineer, and industrial hygienist, personnel specialists and behavioural scientists, statisticians, and equipment and methods engineers.

The "host" might be described in terms of age, sex, body build, economic status, intelligence, behaviour, etc.; the "agent" in terms of type, potential hazard, method of use, mode of injury, etc; and the environment in terms of the effects on the host and/or agent, e.g., temperature, noise, atmosphere, social climate, normal work procedures, activities of neighbours, etc. Such statistical data can suggest preventive methods or further investigations, but the detail and subtlety of many of the factors requires more than a simple reporting and accounting and requires the expertise of specialists. Dr. McFarland and others have shown this method to be well suited to the study of accidents.

ENERGY EXCHANGE MODEL

Dr. J. Gibson noted that ".... injuries to a living organism can be produced only by some energy interchange". Consequently, it was suggested that the "Injury agent" should be the energy exchange which produces the injury rather than the physical object itself, especially since the latter is often difficult to identify. Energy exchanges resulting in injury can be mechanical, chemical, thermal, electrical etc., but are of limited number permitting a reduction of classification of agents. For instance, a blow from a moving object, crushing of a leg in a car, tearing of clothing while stretching are all due to mechanical energy exchanges despite three different physical injury agents, the moving object, the structure of the car, and the stretching body.

This concept is rather naive since all physical events involve energy interchange. However, this classification may be useful for constructing hazard levels, hazard exposure indices, and relating the use and utility of protective devices to specific hazards. In conjunction with the epdemiological model this approach may turn up conflicts, competing risk situations requiring incompatible protective devices.

RISK-TAKING BEHAVIOR MODELS

Several authors have recently suggested models of risk-taking behaviour (Cohen, et al, Suchman, Fox, Rockwell, et al.). Whenever a decision for action must be made in the presence of danger, a degree of risk enters. Two factors affect this degree: the amount of uncertainty as to the present situation and the possible outcome, and the absolute danger of the situation. It is suggested that different persons at different times will take more or less risk. Attempts are being made to elicit the factors affecting such risk-taking to acquire a better understanding. The tacit assumption is that those taking higher risks are more liable to accidents. This is not necessarily true; for instance, risk can only be taken by persons who are aware, at least slightly, of the hazards involved.

This type of decision has the added variable of personal danger and is common in the accident development stages. It is of interest to compare what people estimate they can do, what they will try to do, and what they can actually do in the face of danger. At this point some definitions of terms should perhaps be made. "Danger", "hazard", and "risk" have varied meanings among both laymen and professionals. This author prefers the following definitions: "danger" is the presence of a situation which could inflict injury or damage if an error is made; the "degree of hazard" is the objective probability (i.e., the measured probability) that a man will err in the presence of danger; the "degree of risk" is the subjective probability (i.e., the individuals estimate) that the man will err in the known presence of danger. "Risk taking" is the willing performance of an action which has been judged to have a nonzero degree of risk.

In conclusion, the behaviour of risk taking is only beginning to be understood and warrants further study in relation to accident patterns. Safety engineers should be aware that safe behaviour (low risk taking) is often in conflict with the highly regarded social values of adventurousness, bravery, etc., which entail high risk taking, and that modern society has derived no satisfactory compromise solution.

Probability Models: Three probability models have been discussed widely in the literature on safety. Each of these models is based on a different theory of accident distribution. Stated very simply three distributions are:

1. Chance Distribution - According to this theory, each hazard or unsafe act, however slight the degree of hazard involved, will, if a sufficient number of exposures occur, yield an injury. Which exposure will do so is, in each instance, purely a matter of chance.

2. Biased Distribution - This theory assumes that a person once hurt is thereby likely to be either more or less apt to become an accident victim again. His susceptibility to accidents will have been increased by nervousness or fear, or decreased by greater caution and improved judgment.

3. Unequal Liability - This theory assumes that some persons are much more liable to be involved in accidents than others, that is, they are "accident prone".

Now the probability model makes some questionable assumptions about the accident situation. The most important of these is that an accident represents a uniformly repeatable event, possessing an actual set of probabilities. Since industrial personnel, craftsman, supervisors, the working environment, quality inspectors, interactions with other working groups, etc., are dissimilar, an accident situation has little to make it comparable to a probability model.

Statistical Models: The statistical model is designed to compensate for some of the difficulties of the probability model. This model is based purely on the probabilities, but attempts to take into account the fact that the accident event is not a uniform event. The statistical model attempts to smooth over the irregularities of everyday life and to reduce them to a point where it is reasonable to consider events as if they were ruled probabilistically.

There are several ways of doing this. We can experiment by simulating the accident event over and over again. Of course this is out of the question in the real world. Or we can look over the results of previous accidents and draw out of them similar conditions and events that will stand in place of our repeated experiment. To make this historical study of accidents, a sophisticated statistician will not confine himself to the published data on accident statistics, he will seek out a safety expert to help him isolate factors relevant to establishing uniformly repetitive events from which a set of a'priori probabilities may be derived. Once the statistician has these probabilities he proceeds exactly as in the pure probability model.

An example of a statistical model "THERP" follows:

THERP (TECHNIQUE FOR HUMAN ERROR RATE PREDICTION)

THERP is a quantitative method for evaluating human error. It requires the use of a human error classification system and probability computations. The method of analysis was developed for reducing production defects due to human error in a manufacturing process. But with only slight modification this method is also applicable to human error sources of accidents and can thus be helpful to safety engineers in devising accident countermeasures.

The human error classification system developed by L. W. Rook Jr. as part of the THERP method is shown in the Figure below. The purpose of this error classification system is to provide categories suggestive of the corrective action or countermeasures to be taken. Rules for each category can be developed to help determine the needed countermeasures.

Minimizing human errors in a system can be accomplished by: 1) proper selection and training of personnel for the specific behaviors involved in the system, and 2) redesigning the system so as to improve inputs, simplify mediation processes, and insure accurate outputs. Careful classification of human errors will point to the specific action or remedy required to reduce future errors. For example, an AI type error (intentionally performed action with an input error) indicates that instructions are not clear or that a necessary indicator (scale, dial, or label) is difficult to read, inaccurate, or not understood. Once it is recognized that the error is of this type, it is usually a simple matter to correct the situation.

THERP also involves the concept of a basic error rate, that is, a human error rate that is relatively consistent between tasks requiring similar human performance elements (or behaviors) in different situations. The THERP method assesses the basic error rates in terms of their contributions to specific system failures.

Briefly stated, THERP analysis proceeds as follows: select the specific system failure (or undesired event) to be studied, identify all human operations (or behaviors) performed that affect the event and their associated basic error rates, and compute the probabilities that specific human errors will produce the system failure. The errors are classified in accordance with the error table (Figure below) and the system is altered, i.e., specific corrective actions are introduced. The basic error rates are adjusted by an amount that might be expected from the new procedure and the probabilities are recalculated

The process is repeated until an acceptable level is obtained for the probability of the undesired event. In short, the system is changed on paper and the effects on human error rates due to corrective action are calculated until the analyst is satisfied that the particular failure is unlikely due to human error.

SYSTEM OF HUMAN ERROR CATEGORIES

Error due to acts which are:	Errors due to behavior components of:		
	Input (I)	Media-tion (M)	Output (O)
A - Intentionally performed	AI	AM	AO
B - Unintentionally performed	BI	BM	BO
C - Omitted	CI	CM	CO

NOTE: A - behavior that is properly a part of the task being performed; B - behavior that is not properly a part of the task being performed; C - behavior that should have been performed as a proper part of the task.

More elaborate methods are also available to determine by probability computations how critical specific human errors are for degradation of system performance. These techniques, however, also depend upon basic human error rates.

Basic human error rates are usually expressed in terms of the number of errors per million operations - based upon prior experience in similar situations. Some representative error rates are shown in the figure below to illustrate the range and magnitude of such measurements. (Warning: this data should not be used for computational purposes without additional background information - specifically, under what conditions these rates can be expected to be valid and the probable error in each rate).

Unfortunately the greatest restriction on the use of quantitative human error techniques is the lack of sufficient error rate data. Human error rates specific to Kennedy Space Center personnel can be derived during the research phase of the study.

REPRESENTATIVE HUMAN ERROR RATES
(COMPILED FROM VARIOUS SOURCES)

Task Element

ACTION	OBJECT	ERROR	BER*
Observe	Chart	Inappropriate switch actuation	1,128
Read	Gauge	Incorrectly read	5,000
Read	Instructions	Procedural error	64,500
Connect	Hose	Improperly connected	4,700
Torque	Fluid lines	Incorrectly torqued	104
Tighten	Nuts, bolts	Not tightened	4,800
Install	Nuts, bolts	Not installed	600
Install	O-ring	Improperly installed	66,700
Solder	Connectors	Improper solder joint	6,460
Assemble	Connector	Bent pins	1,500
Assemble	Connectors	Omitted parts	1,000
Close	Valve	Not closed properly	1,800
Adjust	Mechanical linkage	Improper adjustment	16,700
Install	Line orifice	Wrong size installed	5,000
Machine	Valve part	Wrong size drilled & tapped	2,083

*Basic error rate (errors per million operations)

Decision Model - J. Surry has proposed the following decision model for the accident process.

The model has three principle stages, with two similar cycles linking them. Before an accident occurs, first a dangerous situation is built out of a secure situation, and second the danger is released causing injury or damage. It is necessary to separate the behavior of the man during these two phases. Man often courts danger by taking risks in the face of probable danger growth. Indeed, it may be a psychological need to keep the mind alert and interested. If however, he continues to flaunt danger, in face of inevitable injury or damage, his actions are not risk-taking but willful. Thus, the middle stage is defined as that which, if the condition continues unchecked, damage is inevitable. Only by conscious action can it be avoided - the danger is imminent.

The first stage is the total environment, both spatial and temporal, of man. It can be described as infinitum in terms of particular phenomena and their interactions, for instance the physical variables of temperature, atmospheric conditions, spatial layout, man's health and physical condition, etc. and the psychosociological variables describing the man and his human relations, his behavior both past and present, and such vague variables as mood, attitudes, etc. The potential injury agent is also described here in terms of its lethal qualities, and its mode of use by the man. Such environments are constantly being changed by man and nature. This stage is also the present situation of the tasks required, the equipment to be used, the man's knowledge and training, etc.

Every activity of man develops, as does this accident model, out and forward in time from this background "stage".

Now it is assumed that by his action or even non-action, the danger to a man grows out of such an environment. If there are any negative responses to the following questions during the "danger build-up" cycle the danger will become imminent:

a) Is there any warning of the growth of the danger?
b) Can the man see this warning (or detect it by any other sense)?
c) Does he understand the meaning of this warning?
d) Does he know how to avoid such potential danger?
e) Does he choose to avoid it?
f) Is he able to avoid it?

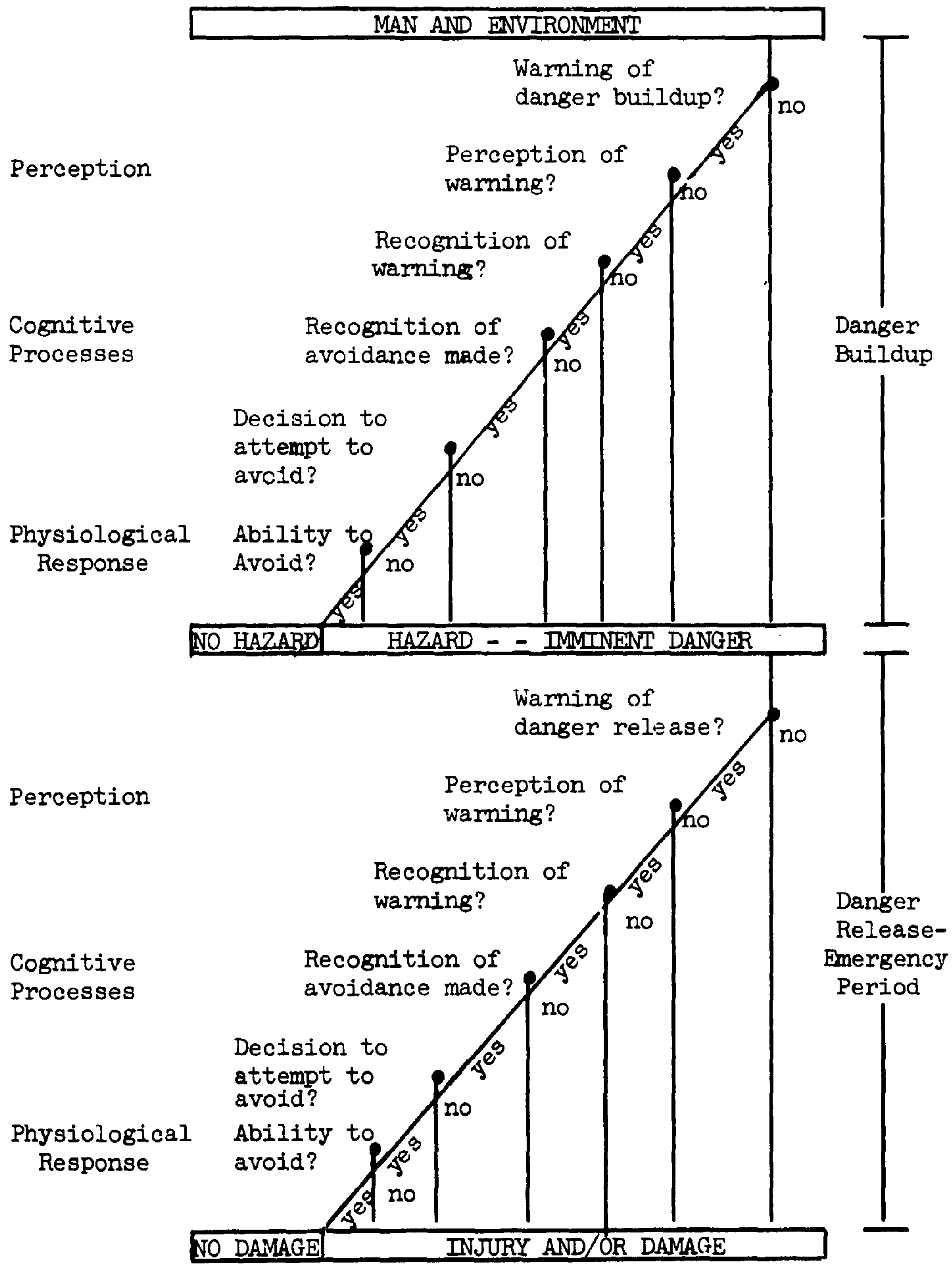
If the replies are all in the affirmative, the danger will not grow and no injury can ensue.

The same series of queries may be posed in the "danger release" cycle:

a) Is there any indication of the danger release?
b) Does the potential victim detect this information?
c) Does he recognize the meaning of this information?
d) Does he know how to avoid the released danger?
e) Does he choose to avoid it?
f) Is he physically capable of avoiding it?

Any negative response to one of these questions will lead inevitably to injury.

An accident can be the result of many different routes through the model (twenty). For example, it is as much an accident if no warning is ever given, as when the warning of danger build-up is misinterpreted. There are fewer routes leading to "no-injury", six altogether with only one in the second phase. Also one route in the second phase leads to suicide when the victim is killed, homicide when another is killed, or deliberate injury or damage, if the warning signs are observed, understood, and the known method of avoidance is not tried. If two men arrive at the second avoidance choice by the same route, despite the fact that neither are actually capable of avoiding injury, the man that makes no attempt to avoid injury is committing self-mutilation, while the man that attempted but failed, had an accident. It can thus be seen how fine the line is sometimes between unpremeditated suicide and accidental death - it essentially hinges on this terminal choice, and the knowledge of the decision has gone with the victim.



A DECISION MODEL OF THE ACCIDENT PROCESS

It will be noted that the difference between the "accident-like" unsafe acts, mishaps, etc., and accidents can be seen from the model. The accident-like events show a buildup of danger, but an avoidance of injury during the "danger release" stage. Thus, these events are not wholly adequate for predicting or studying accidents.

For prediction purposes, if the probability of the positive or negative response at each juncture were known the probability of an accident occurring could be calculated. The probability at each juncture could, hypothetically, be found experimentally by observation of persons at tasks whether or not an accident actually resulted. For instance, in a given situation how many persons are aware of the possible buildup of danger or, when aware of it, how many choose to take the risk?

As a very simple example suppose the probability at each juncture of the first cycle is 95% of having a positive response. Then the probability of danger becoming imminent is $1 - (0.95)^6 = 0.265$ or 26.5%. Then suppose the probability at each juncture during the "danger release" cycle is 70% (since during this phase avoidance is more difficult). The probability of being injured once the danger is imminent is $1 - (0.7)^6 = 0.882$ or 88.2%. Thus, the probability of accidental injury (or suicide) occurring during the task would be predicted to be $0.265 \times 0.882 = 0.234$ or 23.4%. Since the probability of an accident occurring during most tasks is of the order of once in 100,000 hours (.001%), it can be seen by comparison with the above example that the probability of a negative response to any one of the questions is very low (of the order of 0.0005, or half of a tenth of a percent).

The acquisition of the juncture probabilities is difficult and requires some careful observation. This is a point of view that can lead to useful accident research.

<u>Combined Model</u> - The models above represent very tentative hypotheses which are in present accident literature. None have provided a working or predictive model but, rather they suggest the relevant concepts and their importance. On reflection none of the models is incompatible with any of the others, each simply stresses different aspects. It is suggested that by using the competing risk concept modified by the other aspects of abnormal energy exchange, statistical causal sequences, "THERP" error rates, and the more subtle features of human behavior, a more powerful model will be achieved.

This combined model was developed while studying the literature. It should be made clear that this is a preliminary attempt and has no pretensions of finality. It is presented because of the clarification it affords to the quantitative data retrieved from the technical literature. The model will aid in evaluating the utility of the data, indicate gaps in the data necessary to complete the model and identify instances where greater accuracy or more refined breakdowns in the data are required. The combined model embodies most of the concepts propounded in the other models and is an attempt to systematize the accident process in general, and as it applies to industrial craft personnel performing Support Operations tasks in an operational environment at Kennedy Space Center.

The combined model is a Support Operations System Model which uses some of the other models as inputs, some internally, and some models for evaluation and verification. Initial error rates will be inserted as parametric values to be adjusted and modified by real life Support Operations experience.

Inputs to the Model:

THERP Analysis of each industrial craft.

- determination of behavioral elements unique to each craft.
- determination of behavioral elements common to all crafts.
- determination of basic error rate for each behavioral element.

Support Operations mission analysis.

- definition of permanent Support Operations missions.
- definition of planned Support Operations missions.
- time line and functions analysis of each mission.
- time line analysis of personnel subsystem for each Support Operations mission.
- protective equipment/energy exchange analysis for each Support Operations mission.

Support Operations Stress Factors.

- determination of optimistic, expected, and pessimistic values for stress factors.
- determination of density function for stress factors.
- determination of interactions of stress factors.
- determination of risk-taking stress for each occupation.

SECTION 5.

RECOMMENDATION FOR AN EXPERIMENTATION TESTING PROGRAM

(PHASE II)

RECOMMENDATIONS FOR AN EXPERIMENTATION TESTING PROGRAM (PHASE II)

Introduction

In Section 4. a conceptual model was developed for use in predicting the occurrence of human errors which might cause industrial errors. The literature search and survey of industrial accident data sources indicate that the data required for this model has not been reported in either the technical literature or periodic accident data tabulations. Some accident rate data is available giving overall rates for similar industries, and for industrial occupations. The working environment, safety supervision, and hazard exposure at KSC are significantly different than the base of the available data. Available data can be extrapolated on a very limited basis and should be indicative of relative error rates and exposures.

Raw data which has not been tabulated along variables of interest to the study does exist and could be tabulated for phase II to provide more accurate estimates of occupational error, accident, and hazard exposure rates.

Finally, specific data points required for implementation of the model may be derived by carefully designed studies of future accident data collected by NASA and cooperating safety agencies. Although some of the data required is applicable exculsively to KSC Support Operations much of the data required will have broad general application to industrial safety prediction, and the study of man-machine safety.

Overview of the Experimental Program

The experimental program will consist of a group of time-phased tasks many of which can be performed in parallel. Some of these tasks are probably already being performed by NASA personnel for planning purposes and can be coordinated with the safety prediction model with relatively light effort. Other tasks will require some cooperation from accident data banks, and in a few instances from accident source personnel. The main thrust of the study however will be on those tasks required to make the study pertinent to KSC Support Operations.

Determination of Occupational Rates

A series of studies will be designed for each individual occupation of interest. The purpose of the studies will be to determine the human error rates for each behavioral element required by that particular industrial occupation, the resulting accident types and frequencies, the appropriate hazard indices and important stress factors.

In carrying out these studies reference will be made to existing untabulated data currently available, to new data requested from cooperating agencies, and to analytical data developed by the study team. The tools, working environment, supervision, training, operating procedures, used by each

Determination of Occupational Rates (continued)

occupation will be surveyed by skilled human factors personnel for correctible factors known to affect human error rates. For example the tools used by industrial craft personnel with the exception of minor changes in shape, and the introduction of new materials have remained basically unchanged in design for incredibly long periods of time. A recent case where a long-nose pliers used by female production workers was redesigned to conform with both the size of the hand and the correct flexion of the wrist during assembly operations resulted in significant reduction in rejection rate for equipment damaged during assembly. Human factors personnel assigned to this task should be experienced in the use of the tools for the occupation under investigation.

Determination of the Effect of Stress Factors on Occupational Rates

Human factors data on stress factors which affect human error rates is readily available in the form of handbooks and MIL-STANDARDS. This data can be used in its current form to provide initial estimates of the direct and interactive effects of these stress factors on the occupational error rates.

Use of these preliminary stress factor values in the prediction model will permit comparison of theoretical predictions with actual experience. Analytical studies of the differences will provide basis for adjustment of the stress factor values and ultimately the derivation of accurate values pertinent to KSC Support Operations.

Identification of the more significant stress factors may also suggest methods and procedures for getting them under control.

Support Operations Mission Analysis

The definition of pe[illegible]nent and planned Support Operations missions may be available at KSC in sufficient detail for use in the model. The model will require levels of detail for some elements of the mission analysis which may not be currently available. A time line and functions analysis is required for each mission showing each work element, number and type of personnel required, contractor organization, interaction of various contractor groups and the Support Operations administration and supervision.

Finally, an analytic study of protective equipment versus potential energy exchange versus operability for each mission must be performed. The object here is to establish criteria for optimizing the conflicting criteria of being perfectly safe and getting the job done right and on time.

Building the Model

The conceptual model described in the previous section can be programmed for simulation on a general purpose computer. Utilizing the data which will exist at the start of Phase II and the data which will become available after the study will require a computer program capable of easy modification. The modular construction of PL/1 coupled with strong logic handling and indexing features, ease of programming, self-documentation, sophisticated internal diagnostics would seem to make it a logical choice for this application.

Building the Model (continued)

The programming and use of the combined model is seen as an evolutionary process. The program will be produced in modules. Each module will represent an iterative solution to representation of one of the elements of the model. As more data becomes available that module can be replaced by a more sophisticated module or by a group of modules. Extending the simulation programming in this way ensures that a working program is always available while improvements and modifications can easily be inserted or removed.

Testing and verification of individual modules of the program can be carried out in conjunction with analytical studies being performed for other tasks of the study. The model will serve both as an analytical tool and as a test and verification of the efficacy of proposed solutions.

Modeling Technique: Although the combined model is far more complex than any accident model attempted to date, the use of standard information and data processing techniques appear to make this approach both useful and feasible. Data can be grouped in decision tables, charts, distribution functions etc. The following discussion illustrates in detail how a complex decision process may be broken down into elements for ease of study, understanding, and evaluation.

Depicting Complex Decision Patterns: Decision patterns are often too complex to be described by a usable single table. A gigantic piece of paper would be required, and the result would be cumbersome and difficult to read. When a whole system is being documented, a single table is clearly unsuitable.

To show any system, flow of work, or complex pattern as a series of decision tables, it is clearly necessary that the tables be linked. We must proceed through the tables in a logical order. Otherwise, we would be lost in a jumble of tables with no real concept of the decision pattern that the tables were meant to illustrate.

Some sort of control must therefore be kept over the progress from table to table. There must always be an indication as to where to proceed when the end of a rule is reached.

Open Tables: In open tables, the last action of each rule is a directive to the table which will be referenced next. The directive is expressed by the words Go to, followed by the name or number of the referenced table. In limited entry tables, the name appears as part of the statement; there may be a number of such statements, and they may be associated with appropriate rules by an X at the end of the rule. In extended entry tables, the name or number appears in the entry.

Closed Tables: The situation we have just described occurs when control passes completely from one open table to another one. Sometimes, however, control is relinquished temporarily to another table (or series of tables), which does not end with a specific directive as to where to proceed next; such a table is a closed table. When it has been executed in its entirety, control automatically returns to the table which originally directed the user to it.

Especially when there are a number of actions, it may be desirable to execute another table and then return to the original table so that remaining actions can be executed. The use of the term Do, followed by the table name or number, implies that control will be returned to the rule currently being executed. The closed table does not contain an explicit directive on where processing control is to pass; the return to the previous table is usually indicated by the word closed in the table header or by an action entry such as exit or return. The control from the closed table returns to the same rule in the same table which released control, and the next indicated action is taken. This case is the only one in which a table is not entered from the top. Closed tables make it unnecessary to repeat actions and conditions common to more than one rule or table. Also, they permit re-entry to the point within the table referencing them, without having to start at the normal entry point at the top of the table.

Action Tables: At times, a long series of actions, applying to several sets of conditions, may make a table long and difficult to work with. These actions can be removed and put into a separate table called an action table. The action table consists only of a list of actions. Since all the actions will always be performed, there is no need for conditions, whose function is only to specify a pattern of actions to be performed. Such a table is normally a closed table.

Certain actions may be used only once during the course of an operation. A good example is the "housekeeping" routine associated with the start of a computer program. Actions like these are best put into a separate table so that they are not considered over and over. Attention can be focused on such seldom used actions only when it is actually necessary to perform them.

The Flow of Logic: The following figure is a diagram of how logic flows through a series of open and closed tables. Let us follow a procedure in its path through these tables.

We start at TABLE 1, and the last executed action sends us to TABLE 2. Following the selected rule in TABLE 2, the action Do TABLE 8 sends us to TABLE 8, which is a closed table. After the appropriate rule in TABLE 8 is followed, control returns to the same rule in TABLE 2 which sent the control to TABLE 8, and the next indicated action is taken. This action, Do TABLE 9, sends us to TABLE 9, after which we again return to the next action in TABLE 2. The action Go To TABLE 4 sends us to the open TABLE 4. Following the indicated rule in TABLE 4, we again Do TABLE 9 before returning to TABLE 4, which in turn sends us to TABLE 1 to repeat the entire process.

As we see from this example, it is possible for several tables to use the same closed table. In other circumstances, we might also have closed tables with no conditions, as we discussed in the previous section on action tables. Another situation which may also occur is that one closed table may reference another closed table; we shall see an example of this situation before the chapter closes.

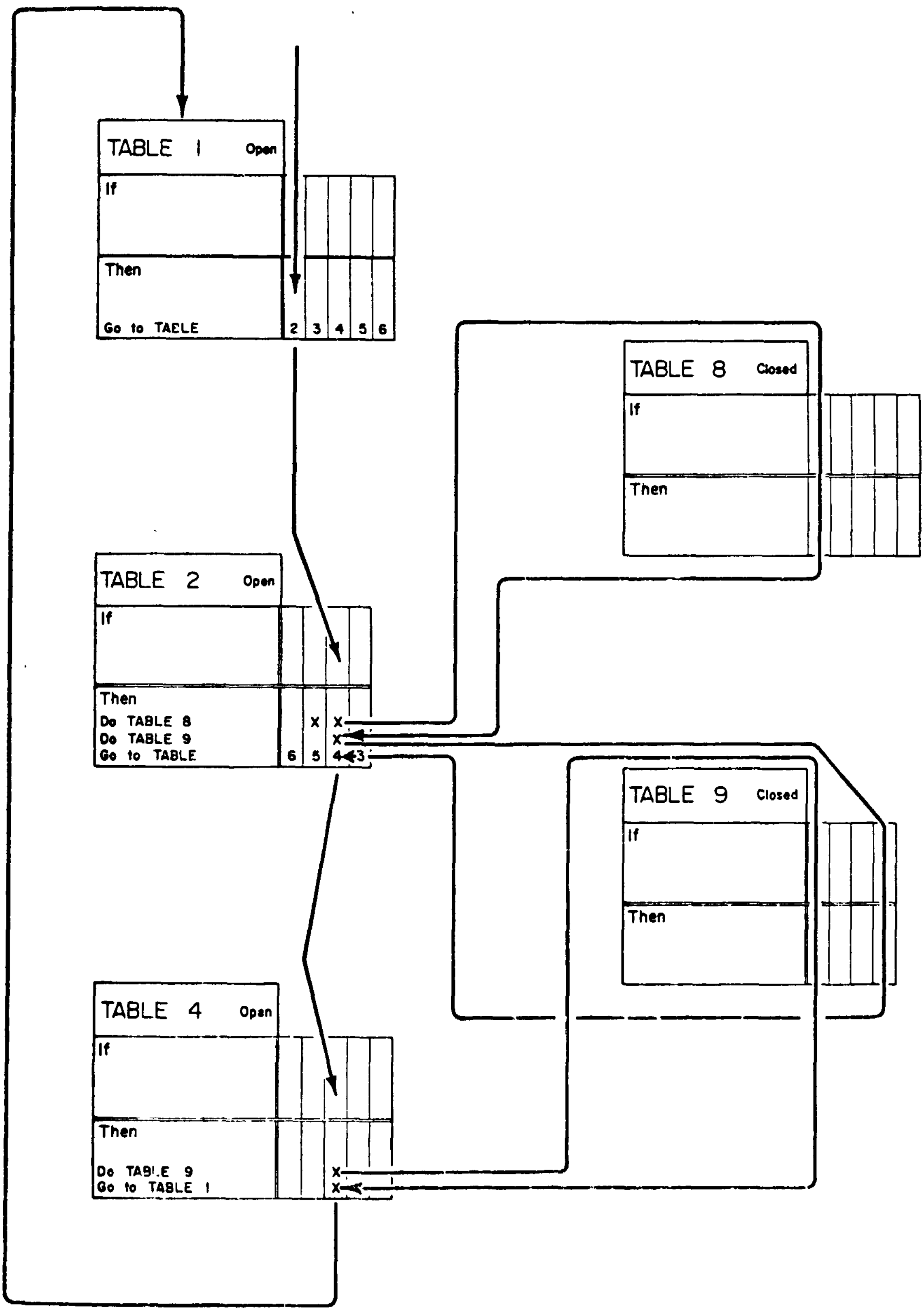


TABLE 1 Open
If
Then
Go to TABLE
2 3 4 5 6
TABLE 8 Closed
If
Then
TABLE 2 Open
If
Then
Do TABLE 8
Do TABLE 9
Go to TABLE
6 5 4 3
X X
X
TABLE 9 Closed
If
Then
TABLE 4 Open
If
Then
Do TABLE 9
Go to TABLE 1
X
X

SUPPORT OPERATIONS TASK ELEMENT		1	2	3	4	5	6	7	8	9	10
A	Stage* is	I	I	I	I	II	II	III	III	IV	IV
B	Search & Evaluation ok	Y	Y	Y	N						
C	Corrective Action Known	Y	N	N							
D	Causes known		Y	N							
E	Causes discovered					Y	N				
F	Corrective Action Discovered										
G	Tests ok									Y	N
H	Test Corrective Action	X						X			
I	Research		X			X					
J	Research causes			X							
K	Change stage designation to	IV	III	II		III		IV			
L	Pass through table again	X	X	X		X		X			
M	Terminate				X		X		X		X

*Beginning of project stage is I.

SAMPLE DECISION TABLE

Conclusion: The Support Operations Simulation Model is an evolutionary model. As it develops, it will provide an increasingly accurate means of both predicting and analyzing the human component of the safety equation. As the model evolves and incorporates more descriptive and refined elements it will become increasingly ethnographic in character. This should be expected as rational descriptions of behavior and should include the human community or reference group in which they are made and therefore must be examined in terms of the structures of those reference groups.

Summary of Safety Data Which Supports Model Construction: The tabulations of quantitative data available from current data sources and retrospective studies is not directly applicable to the operational situation that exists at the Kennedy Space Center. Although some data is available which suggests gross accident rates for the various industrial crafts of interest these rates cannot be used directly in models used for the Support Operations group. The quality and intensity of safety supervision at the Space Center exceeds that at conventional industrial locations by an order of magnitude. The nature and severity of hazards on the other hand are sometimes identical, and in other cases defy direct comparison.

Other human factors data available in government standards and handbooks relating to human capabilities and limitations, environmental effects, social, psychological, physiological, etc., factors are directly applicable.

Gaps in the Safety Data:

- Determination of occupational accident types, rates, hazard exposure indices etc.
- Determination of behavioral elements common to all crafts.
- Determination of behavioral elements unique to each craft.
- Determination of basic error rates for each behavioral element.
- Determination of the interaction effects of stress factors with each other and all of the above.
- Determination of risk-taking stress for each of the occupational groups.

APPENDIX A

TABULAR RESULTS OF LITERATURE SEARCH

The following tables comprising the tabular results of the literature search have been extrapolated and condensed from a variety of the sources found during the literature search. The majority of the data was found in the various U.S. Department of Labor, Bureau of Labor Statistics publications. Other sources for this tabulation are the Edison Electric Institute Bulletin and the injury publications of the states of California and Pennsylvania.

UNSAFE ACTS BY INDUSTRIES: PERCENTAGE OF REPORTED DISABLING INJURIES

	CONCRETE BRICK AND BLOCK INDUSTRY	WAREHOUSES 1950	HOSPITALS 1963	HOTELS
Operating without authority, failure to secure or warn	5.5	3.4	3.5	3.4
Operating or working at unsafe speed	2.3	3.2	1.3	3.6
Using unsafe equipment or equipment unsafely	23.7	28.7	1.1	3.4
Taking insecure hold	50.7	37.5		6.7
Taking wrong hold	23.6	43.2		7.1
Other	25.7	19.3		2.2
Unsafe loading, placing, piling	2.9	7.2	0.6	2.6
Taking unsafe position or posture	38.4	26.0	3.1	3.8
Inattention to footing	36.2	42.0	9,709 } 31.2	1,405 } 35.4
Inattention to surroundings	15.5	14.9	9,709	1,405
Lifting with bent back or in awkward position	25.3	15.9		10.4
Other	23.1	27.2		
Failure to wear safe attire or use personal protective equipment	1.5	1.8	2.5	0.5
Other	0.8	0.5	2.0	1.9
Unclassified	24.7	29.2	11.2	18.1
No Unsafe Act	-	-	12.1	-
Horse play	-	-	-	1.1
Improper use of hands or body parts	-	-	31.5	-

UNSAFE ACTS BY TYPE OF ACCIDENT
GAS INDUSTRY 1968*

ACCIDENT TYPE	Inattention to Footing or Surroundings.	Taking Unsafe Position or Posture	Driving Errors	Unsafe Act. N.E.C. Unclassified	Improper Use of hands or Body Parts	Unsafe Placing/Mixing, Combining, etc.	Operating or Working at Unsafe Speed	Failure to Secure or Warn	Improper Use of Equipment	Failure to Use Pers. Prot. Equip. or Attire	No Unsafe Act	Inadequate Data	Miscellaneous***	TOTAL
Overexertion In Lifting or Pulling or Pushing Objects	16	81	-	6	12	-	6	-	3	-	15	1	-	140
Struck by Falling or Flying Objects	28	11	4	10	16	8	3	11	7	3	10	3	3	117
Falls on Same Level to Working Surface	69	2	-	-	-	1	3	1	-	-	4	1	1	82
Falls to Different Level from Platforms, Ladders, on Stairs, etc.	40	7	1	7	1	4	5	1	1	1	-	-	1	69
Bodily Reaction from Involuntary and Voluntary Motions	32	7	-	2	-	1	3	-	-	-	16	-	-	61
Struck Against Stationary or Moving Object ..	32	3	-	3	-	1	3	2	4	1	5	-	2	56
SUBTOTAL	217	111	5	28	29	15	23	15	15	5	50	5	7	525
Miscellaneous**	26	11	47	17	6	16	-	4	2	9	14	31	5	188
TOTAL	243	122	52	45	35	31	23	19	17	14	64	36	12	713

*713 Cases Voluntarily submitted by 80 companies, 74% Gas Distribution Cons.

**Miscellaneous Accident Type Includes the Following: Motor-Vehicle Accidents; Contact with Temperature Extremes; Caught in, Under or Between; Contact with Radiations, etc.; Unclassified; Insufficient Data; Animal Bites; Rubbed or Abraded; Accident Type, N.E.C.; Contact with Electric Current; and Explosions.

***Miscellaneous Unsafe Act Includes the Following: Cleaning, Oiling, Adjusting or Repairing Moving Electrically Energized, or Pressurized Equipment; Horseplay; Using Unsafe Equipment; Making Safety Devices Inoperative and Unsafe Leak Detection Practices.

FOUR YEAR SUMMARY OF FATAL ACCIDENTS
IN THE ELECTRICAL LIGHT AND POWER INDUSTRY
1960 through 1963

ACT	PRIMARY CAUSES	SECONDARY CAUSES	SEVERAL CAUSES
Unsafe Act By Injured	61	23	97
Unsafe Act By Another	5	8	31
Rules Not Followed	35	36	74
Improper Work Method	18	14	83
Improper Supervision	9	20	52
Equipment Failure	4	0	5

ELECTRICAL WORK INJURIES INVESTIGATED, UNSAFE ACT BY ACCIDENT TYPE, CALIFORNIA, 1968

Unsafe act	Total	Contact with: Energized Parts: Directly (bare parts)	Contact with: Energized Parts: Through tools or equipment	Contact with: Parts not normally energized	Contact with: Heat caused by: Arc, explosion caused by arc or short circuit	Contact with: Heat caused by: Electrical ignition of gases, vapors, etc.	Other	Accident type not reported
Total	825	233	107	226	195	8	35	21
No unsafe act	244	15	10	139	68	1	10	1
Failure to de-energize equipment or to lock open isolating switches or circuit breakers	143	73	19	11	38	1	1	-
Use of defective or unsafe tools or equipment	57	12	2	29	13	-	1	-
Assuming an unsafe position	122	84	9	4	17	1	7	-
Use of tools or equipment too near bare energized parts	61	7	38	2	14	-	-	-
Failure to use proper personal protective equipment	25	11	5	1	6	-	2	-
Defeated safety interlock in energized cabinet or other enclosure	4	4	-	-	-	-	-	-
Pulled or lifted tools or equipment by cord	3	1	-	2	-	-	-	-
Opened circuit operating under load	3	-	-	-	2	1	-	-
Misuse or misapplication of tools or equipment, n.e.c.	42	3	10	13	15	-	1	-
Unsafe act by others	44	8	9	10	9	2	5	1
Other unsafe act, n.e.c.	35	11	2	8	5	2	7	-
Insufficient information to classify	42	4	3	7	8	-	1	19

n.e.c.--Not elsewhere classified.

STUDY TO GET COMPREHENSIVE INFORMATION ABOUT THE OCCURRENCE OF ACCIDENTS IN SAWMILLS

UNSAFE ACTS	PERCENTAGE
Improper Use of Hands, Body	26.5
Inattention to Footing	26.5
Unsafe Position or Posture	25.9
Unsafe Loading, Placing, Piling	5.4
Repairing, Cleaning, Moving, Equipment	4.0
Failure to Secure or Warn	3.9
Working at Unsafe Speed	3.1
Failure to Wear Safe Attire	1.9
	97.2%

WORK ACCIDENTS IN HOSPITALS, SELECTED BY OCCUPATION AND UNSAFE ACT, 1963

Occupation	Total number of injuries	Unsafe Act										
		Improper use of hands or body parts	Inattention to footing or surrounding	Failure to secure or warn	Failure to use personal protective equipment	Taking unsafe position or posture	Improper use of equipment	Operating or working at unsafe speed	Unsafe placing, mixing, combining	Other	No Unsafe Act	Unclassified
Total	31,148	9,827	9,709	1,095	764	957	356	410	173	610	3,751	3,485
Ambulance Driver	54	13	26	--	--	--	--	--	--	1	7	7
Anesthesiologist	52	3	49	--	--	--	--	--	--	--	--	--
Attendant......	3,364	847	901	43	23	47	32	32	6	132	941	362
Beautician.....	73	13	20	6	--	6	--	1	--	--	19	9
Butcher........	30	20	1	1	--	--	--	--	--	--	3	4
Carpenter......	260	132	17	16	9	--	--	--	--	--	53	33
Cook, baker, & helper.......	1,250	357	555	14	19	--	6	57	4	62	69	108
Custodial worker........	1,137	336	348	113	14	62	3	1	17	96	92	56
Electrician....	172	76	24	9	3	--	--	--	--	1	7	50
Handyman	331	105	60	54	22	13	3	9	9	--	22	36
Housekeeper	388	77	173	11	3	50	4	--	3	3	10	53
Laboratory Helper.......	21	--	9	--	1	--	3	1	--	--	3	4
Laboratory Technician...	464	16	153	43	3	43	--	--	44	--	54	108
Maid...........	1,060	212	404	98	66	27	--	4	4	3	60	182
Maintenance Engineer.....	192	68	20	93	--	3	--	--	--	--	3	6
Painter........	287	39	62	7	--	20	1	3	1	3	49	102
Plumber........	156	41	17	3	1	9	1	--	--	9	1	73
Repairman General......	742	235	211	21	17	7	53	10	--	59	33	96
Stationary Engineer.....	250	73	86	3	--	--	--	7	46	1	3	30

WORK ACCIDENTS IN HOSPITALS, SELECTED BY OCCUPATION AND UNSAFE ACT, 1963 (cont'd)

Occupation	Total number of injuries	Improper use of hands or body parts	Inattention to footing or surrounding	Failure to secure or warn	Failure to use personal protective equipment	Taking unsafe position or posture	Improper use of equipment	Operating or working at unsafe speed	Unsafe placing, mixing, combining	Other	No unsafe act	Unclassified
Steamfitter....	30	3	3	6	9	--	--	--	--	--	10	--
Technician Not elsewhere classified...	303	96	100	3	--	86	--	--	--	--	7	9
Telephone Op...	118	--	110	--	--	--	--	--	--	6	--	1
Truck Driver	76	37	17	1	--	1	--	1	--	4	1	11
Other	330	151	105	--	9	--	1	43	1	--	6	14

UNSAFE ACT BY INDUSTRY, WORK INJURIES IN PENNSYLVANIA - 1968

INDUSTRY	UNSAFE ACT										
	OPERATING WITHOUT AUTHORITY OR PROPER CLEARANCE	OPERATING OR WORKING AT UNSAFE SPEEDS	MAKING SAFETY DEVICES INOPERATIVE	USING UNSAFE EQUIPMENT OR USING EQUIPMENT UNSAFELY	OVERLOADING, CROWDING, POOR ARRANGEMENT	UNNECESSARY EXPOSURE TO DANGER	WORKING ON MOVING OR DANGEROUS EQUIPMENT	DISTRACTING TEASING, ABUSING, STARTLING	FAILURE TO USE SAFETY OR PROTECTIVE DEVICES	NOT ELSEWHERE CLASSIFIED	NO UNSAFE ACT
Total Fatal	4	3	-	281	39	130	4	4	6	22	133
Total NonFatal	260	690	6	58,068	7,007	22,358	368	105	1,988	386	4,650
MANUFACTURING INDUSTRIES - TOTAL	136	269	2	24,393	3,050	8,227	274	44	1,099	152	581
Food	22	35	-	3,319	284	1,146	43	8	50	20	80
Textiles	1	7	-	1,128	114	314	17	3	29	10	34
Apparel	2	2	-	1,350	71	257	5	1	12	9	35
Lumber	3	10	-	767	135	142	4	-	27	1	14
Furniture	3	4	-	772	107	249	7	2	21	6	12
Paper	7	12	-	1,040	130	323	41	1	25	5	18
Printing	2	5	-	772	80	250	12	1	12	6	24
Chemicals	9	8	-	572	75	248	10	1	43	12	33
Petroleum Refining	1	4	-	261	24	109	-	2	5	1	8
Rubber	5	4	-	693	81	255	11	2	32	5	19
Leather	2	5	-	646	40	121	2	1	9	3	21
Stone, Clay, and Glass	8	18	1	1,262	202	641	16	-	67	7	28
Primary Metals	20	60	-	3,624	524	1,328	34	7	245	14	65
Fabricated Metals	14	28	-	2,944	423	943	24	2	189	20	47
Machinery (Except Electrical)	7	25	1	1,954	299	746	14	4	152	11	40
Machinery (Electrical)	9	10	-	1,128	145	390	12	7	59	6	36
Transportation Equipment	10	23	-	1,115	191	413	7	1	80	4	31
Other Manufacturing	11	9	-	1,046	125	352	15	1	42	12	36
NONMANUFACTURING INDUSTRIES - TOTAL	124	421	4	33,675	3,957	14,131	94	61	889	234	4,069
Agriculture	3	11	-	704	61	174	8	2	22	1	87
Anthracite Mining	-	8	-	425	78	102	2	-	24	-	10
Bituminous Mining	6	11	-	761	231	248	4	-	12	-	9
Mining and Quarrying	-	6	-	170	27	52	2	-	5	1	3
Crude Petroleum & Natural Gas	-	-	-	65	11	18	-	-	4	-	1
Construction (Building)	1	17	-	1,645	219	519	-	2	58	8	38

UNSAFE ACT BY INDUSTRY, WORK INJURIES IN PENNSYLVANIA - 1968 (continued)

INDUSTRY	UNSAFE ACT										
	OPERATING WITHOUT AUTHORITY OR PROPER CLEARANCE	OPERATING OR WORKING AT UNSAFE SPEEDS	MAKING SAFETY DEVICES INOPERATIVE	USING UNSAFE EQUIPMENT OR USING EQUIPMENT UNSAFELY	OVERLOADING, CROWDING, POOR ARRANGEMENT	UNNECESSARY EXPOSURE TO DANGER	WORKING ON MOVING OR DANGEROUS EQUIPMENT	DISTRACTING, TEASING, ABUSING, STARTLING	FAILURE TO USE SAFETY OR PROTECTIVE DEVICES	NOT ELSEWHERE CLASSIFIED	NO UNSAFE ACT
Construction (Other)	5	27	-	1,178	176	395	3	-	54	16	33
Construction (Special)	7	32	-	2,853	414	908	8	-	120	25	79
Railroads	2	1	-	183	19	71	4	-	6	2	7
Local Transportation	-	4	-	458	42	623	3	3	5	3	110
Motor Freight	12	63	-	2,361	389	1,375	6	3	50	9	52
Other Transportation	2	8	-	426	69	182	-	-	14	2	19
Communication and Utilities..	2	8	3	538	42	301	5	-	34	12	31
Wholesale Trade	16	31	-	2,644	443	1,282	12	7	94	24	85
Retail Trade	34	53	-	7,290	819	2,672	10	18	137	56	236
Finance	5	12	-	831	73	277	3	2	9	10	66
Services	12	41	-	4,529	395	1,692	11	12	93	33	487
State Government	8	13	1	1,673	114	673	3	6	32	6	490
Local Government	9	75	-	4,935	334	2,565	10	6	116	26	2,225
Federal Government	-	-	-	6	1	2	-	-	-	-	1

WORK ACCIDENTS TO WAREHOUSEMEN OF 245 WAREHOUSES, 1950,
CLASSIFIED BY UNSAFE ACT AND ACCIDENT TYPE

UNSAFE ACTS	TOTAL NUMBER OF ACCIDENTS	STRUCK BY MOVING OBJECTS			OVER-EXERTION	CAUGHT IN, ON, OR BETWEEN	FALLS			STRIKING AGAINST	SLIPS STUMBLES	INHALATION, ABSORPTION	CONTACT WITH EXTREME TEMPERATURES	OTHER	UNCLASSIFIED
		TOTAL	FALLING OBJECTS	OTHER			TOTAL	TO LOWER LEVELS	ON SAME LEVEL						
Total	1,477	459	317	142	324	257	181	109	72	136	71	24	12	8	5
Using Equipment Unsafely.	424	154	113	41	68	141	6	2	4	46	6	2	-	1	-
Taking Wrong Hold of Objects	183	20	4	16	44	92	1	-	1	25	-	-	-	1	-
Gripping Objects Insecurely	159	123	109	14	17	6	2	2	-	11	-	-	-	-	-
Pulling Instead of Pushing Handtrucks	60	9	-	9	2	39	3	-	3	2	5	-	-	-	-
Using Hands Instead of Equipment	16	1	-	1	4	4	-	-	-	6	1	-	-	-	-
Other	6	1	-	1	1	-	-	-	-	2	-	2	-	-	-
Taking Unsafe Positions or Postures	303	60	28	32	74	60	112	76	36	33	39	-	1	4	-
Inattention to Footing	161	16	14	2	-	10	89	58	31	6	39	-	1	-	-
Lifting With Bent Back	61	-	-	-	57	-	-	-	-	-	-	-	-	4	-
Inattention to Surroundings	57	13	3	10	-	19	1	1	-	-	24	-	-	-	-
Exposure to Moving Equipment	29	7	1	6	-	22	-	-	-	-	-	-	-	-	-
Exposure to Falling or Rolling Objects	14	6	5	1	6	2	-	-	-	-	-	-	-	-	-
Other	61	18	5	13	11	7	22	17	5	3	-	-	-	-	-
Unsafe Loading or Placing	106	76	73	3	6	17	2	2	-	4	-	-	1	-	-
Failing to Secure or Warn	50	24	11	13	1	24	-	-	-	-	-	-	-	-	1
Failure to Look or Block	29	14	11	3	1	24	-	-	-	-	-	-	-	-	-
Failure to Warn	21	10	-	10	-	10	-	-	-	-	-	-	-	-	1

WORK ACCIDENTS TO WAREHOUSEMEN OF 245 WAREHOUSES, 1950,
CLASSIFIED BY UNSAFE ACT AND ACCIDENT TYPE (cont'd)

UNSAFE ACTS	TOTAL NO. OF ACCI-DENTS	STRUCK BY MOVING OBJECTS			OVER-EXER-TION	CAUGHT IN, ON, OR BE-TWEEN	FALLS			STRIK-ING AGAINST	SLIPS STUM-BLES	IN-HALATION AB-SORP-TION	CONTACT WITH EXTREME TEMPER-ATURES	OTHER	UNCLAS-SIFIED
		TOTAL	FALL-ING OB-JECTS	OTHER			TOTAL	TO LOWER LEVELS	ON SAME LEVEL						
Operating or Working at Unsafe Speeds...........	48	20	10	10	11	2	2	1	1	5	7	-	-	1	-
Throwing Objects Instead of Passing	19	7	5	2	11	1	-	-	-	-	-	-	-	-	-
Other..................	29	13	5	8	-	1	2	1	1	5	7	-	-	1	-
Failing to Wear Personal Safety Equipment.........	27	4	-	4	1	2	2	2	-	17	-	1	-	-	-
Other	7	1	-	1	-	3	-	-	-	1	-	-	1	1	-
Unclassified; Insuf Data..................	432	120	82	38	163	8	57	26	31	30	19	21	9	1	4

	FREQUENCY RATE OF DISABLING INJURIES REPORTED					
	CONST. CO. 1948	HEAVY CONST. INDUSTRY 1961	HIGHWAY CONST. 1961	WARE-HOUSES 1961	FLUID MILK INDUSTRY 1952	BOILER-SHOP PRODUCTION 1951
Air Compressor Operator	62.7	9.8*	18.4	48.2		
Airtool Operator						
Boilermaker	32.4					
Carpenter	38.2	33.0	44.3			
Electricians	23.1	24.5				
Ironworker, Structural	53.9	16.1*				
Maintenance Men, General	55.7			37.2	30.1	
Machine Operator, N.E.C.		24.3	27.3			38.3
Millwrights	21.1	4.5*				
Mechanics		33.2	38.1			
Pipefitters	42.9	28.9				
Plumbers	29.5	22.1*				
Crane & Winch Operator	31.5	12.4	24.7			22.5
Tractor Operator	32.4	16.4	24.5			
Riggers	41.5					
Sheet Metal Workers	33.1					
Steam Fitters	30.4					
Truck Drivers	30.3					
Welders	88.4	41.3				34.7

* Based on an exposure of less than 1 million employee-hours work during the year

Per Cent of Total Work Injuries for the Selected Occupation by Selected Industry Group, in Pennsylvania - 1968

Occupation	Chemicals and Petroleum	Metals	Crude Petroleum & Natural Gas	Contract Construction	Transportation and Public Utilities	State Government	Local Governments
Total Fatal	14	98		90	90	40	52
Total Nonfatal	1,426	17,485	99	8,840	7,564	3,019	10,301
Auto Mechanics	1.1	0.6	1.0	1.1	4.4	0.9	0.7
Boilermakers	0.4	0.3	---	0.3	0.03	--	--
Carpenters	0.7	0.5	---	13.5	0.1	0.6	0.1
Chemical Workers	7.0	---	---	----	----	---	---
Construction Engineers	----	---	---	0.1	----	0.1	---
Cranemen	0.1	1.1	---	0.4	*	---	*
Drug Makers	1.7	---	---	----	----	---	---
Electricians	0.5	0.7	---	4.0	0.4	0.5	0.3
Erectors	0.1	0.2	---	0.2	----	---	---
Handymen	----	0.1	---	0.1	*	---	*
Laboratory Workers	0.4	0.1	---	-----	----	*	*
Machine Operators, N. O. C.	7.6	10.8	---	0.6	0.3	0.3	0.2
Machine Operators (Portable)	0.2	0.8	21.0	1.1	0.1	*	0.1
Machinists	0.9	5.3	11.0	0.1	0.4	*	*
Maintenance Men	3.2	1.5	1.0	0.3	0.6	0.3	1.9
Millwrights	0.1	1.1	---	0.3	----	---	----
Plumbers - Gas & Steam Fitters	0.1	0.1	---	4.7	*	0.2	0.2
Powder Mill Workers	0.1	----	---	----	----	---	-----
Professional Instrument Workers	---	0.1	---	----	----	---	-----
Radio and T.V. Technicians	---	*	---	----	0.1	*	-----
Repairmen - Others	1.8	1.0	2.0	0.9	2.1	0.6	0.3
Riggers	0.4	0.6	---	0.1	11	---	*
Sheet Metal Workers	---	109	---	1.4	5*	---	*

Continued

Per Cent of Total Work Injuries for the Selected Occupation by Selected Industry Group, in Pennsylvania - 1968 (cont'd)

Occupation	Chemicals and Petroleum	Metals	Crude Petroleum & Natural Gas	Contract Construction	Transportation and Public Utilities	State Government	Local Governments
Structural Iron Workers	-----	0.3	-----	2.1	*	----	0.1
Truck Drivers	6.9	1.4	6.0	3.2	35.1	2.6	3.3
Welder - Acetylene	0.7	5.4	-----	1.3	0.5	0.1	8*

* Less than 0.1% of work injuries

PHILADELPHIA NAVAL SHIPYARD

Lost Time Accidents 1949-1955
(for 6 Years 6 Months)

UNSAFE ACT	NO.	PERCENT
Distracting, Teasing, Abusing, Startling	2	0.5
Failure to Use Safe Attire Personal Protective Devices	16	4.0
Moving or Dangerous Equipment	10	25.0
Operating at unsafe Speed	13	3.2
Operating Without Authority	23	5.7
Safety Devices Inoperative	7	1.7
Unsafe Loading, Placing, Mixing	42	10.4
Unsafe Position or Posture	164	40.7
Using Equipment Unsafely	44	10.9
No Unsafe Act	56	13.9
N.E.C.	26	6.5
	403	100.0%

TYPE OF ACCIDENT	NO.	PERCENT
Caught In, On or Between	57	14.1
Contact with Electric Current	9	2.2
Exposure to Temperature Extremes Including Burns	30	7.4
Fall on Same Level	28	7.0
Fall to Different Level	50	12.4
Foreign Bodies in Eye	2	0.5
Inhalation, Absorption Swallowing	8	2.0
Slip (Not Fall) or Overexertion	109	27.0
Striking Against	35	8.7
Struck By	68	16.9
Not Elsewhere Classified	7	1.7
	403	99.9%

PHILADELPHIA NAVAL SHIPYARD - Lost Time Accidents 1949-1955 (cont'd)

UNFSAFE PERSONAL FACTOR	NO.	PERCENT
Bodily Defects	12	3.0
Improper Attitude	149	37.0
Lack of Knowledge or Skill	160	39.7
No Unsafe Personal Factor	69	17.1
Not Elsewhere Classified	13	3.2
	403	100.0%

APPENDIX B

RESULTS OF SAFETY DATA SURVEY

The Industrial Occupation Accident Data Survey was mailed to 309 sources of safety data. These sources and their addresses were obtained from The National Safety Council's "Accident Prevention Manual for Industrial Operations", the Air Force System Command Design Handbook series "System Safety" and the list of NASA field offices supplied by NASA Headquarters.

Twelve (3.9%) of the questionnaires were returned with the addressees unknown. Seventy-eight (25.2%) of the questionnaires were returned filled out and 42 (13.6%) were returned as not being applicable to that particular organization, and 177 (57.3%) of the organizations did not respond at all or in time to be included in these results. A copy of the letter sent to the sources of safety data follows the tabulated results.

TABULATION OF ANSWERS

INDUSTRIAL OCCUPATION ACCIDENT DATA SURVEY

		YES	NO	NO ANSWER
1.	Are you a central collection point for various sources of accident data?	73	5	0
2.	Do you control or have any influence over the method and/or content of the accident data sent to you?	61	15	2
3.	Do you or your sources of data use "The American Standard Cause Code? for reporting accidents?	37	41	0
4.	Do you perform any analysis on the collected data?	62	16	0
6.	Is your data available for additional anslysis by other agencies?	43	33	2

7. In what form is the untabulated accident data?

DATA SHEETS	35
PUNCHED CARDS	25
MAGNETIC TAPE	17
OTHER	20
NO ANSWER	2

8. How is the tabulated accident data stored?

DATA SHEETS	35
PUNCHED CARDS	27
MAGNETIC TAPE	18
OTHER	16
NO ANSWER	5

TABULATION OF ANSWERS - Industrial Occupation Accident Data Survey (cont'd)

		YES	NO	NO ANSWER
9.	Do your records break down accidents by:			
	INDUSTRY	55	18	5
	OCCUPATION	35	34	9
	UNSAFE ACT	29	40	9
	QUALITY OF SAFETY SUPERVISION	8	56	14
	EXPERIENCE OR TRAINING LEVEL	12	55	11
	HAZARD ANALYSIS	21	45	12
	OTHER	25	17	36
10.	Do your accident reports include the specific working conditions/ environment?			
	HEIGHT	21	44	13
	SLIPPERY PLATFORM	23	43	12
	RAIN	20	46	12
	PROTECTIVE CLOTHING	18	46	14
	ILLUMINATION	17	45	16
	NOISE LEVEL	12	48	18
	OTHER	15	25	38
11.	Is there any recording of unsafe acts which did not result in lost time, require medical treatment, damage equipment, or cause delays in time?	22	55	1
13.	Do you use the "Standard Industrial Classification 1957 Revision" for your breakdown of industry classification?	30	42	6
14.	Are your accident data collected as a result of laws or regulations?	44	32	2
15.	Do you or any associated agency perform detailed investigations of the causes of accidents?	48	25	5
	Or, do you accept the reported cause of the accident?	42	18	18

TABULATION OF ANSWERS - Industrial Occupation Accident Data Survey (cont'd)

	YES	NO	NO ANSWER
16. Do you distribute or publish special or regular reports which are available?	52	20	6

714-871-3232

HUGHES AIRCRAFT COMPANY

FULLERTON, CALIFORNIA 92634

8 May 1970

Contract - NAS 10-6976

Gentlemen:

Hughes Aircraft Company is presently under contract to the John F. Kennedy Space Center (NASA) to survey potential sources of quantitative data relating to industrial accidents. The ultimate purpose of the study is to extend the basic principles of reliability engineering to the human element. The results of the study should provide indications as to the probability of human errors impacting critical operations, methods for improving human reliability, and methods for the evaluation of the adequacy of operating procedures.

We are interested in developing experiential accident rates for each industrial occupation. Further breakdowns of the accident rates experienced by industrial occupations under different hazard conditions will be made if the data can be located. Accident data related to the various types of skilled and semiskilled industrial "craft" jobs are sought.

Consequently, we would like to enlist your aid in filling out the attached questionnaire, appending pertinent comments, and a bibliography of your publications. A copy of our final report will be sent to all respondents.

Sincerely yours,

J. E. Karroll (gb)

J. E. Karroll, Program Manager
Human Reliability Study

JEK/nl

INDUSTRIAL OCCUPATION ACCIDENT DATA SURVEY

Questionnaire filled out by:

NAME: ______________________

TITLE: ______________________

ORGANIZATION: ______________________

ADDRESS: ______________________

____

____

1. Are you a central collection point for various sources of accident data?

YES _____ NO _____

If yes, list typical sources of data:

2. Do you control or have any influence over the method and/or content of the accident data sent to you?

YES _____ NO _____

3. Do you or your sources of data use "The American Standard Cause Code" for reporting accidents?

YES _____ NO _____

If no. briefly outline the standard used:

4. Do you perform any analysis on the collected data?

YES _____ NO _____

5. If analyses of accident data other than summarization are performed please list typical studies:

6. Is your data available for additional analysis by other agencies?

YES _____ NO _____

7. In what form is the untabulated accident data?

DATA SHEETS _____ PUNCHED CARDS _____ MAGNETIC TAPE _____

OTHER _____

If other, please describe:

8. How is the tabulated accident data stored?

DATA SHEETS _____ PUNCHED CARDS _____ MAGNETIC TAPE _____

OTHER _____

If other, please describe:

9. Do your records break down accidents by:

	YES	NO
INDUSTRY	____	____
OCCUPATION	____	____
UNSAFE ACT	____	____
QUALITY OF SAFETY SUPERVISION	____	____
EXPERIENCE OR TRAINING LEVEL	____	____
HAZARD ANALYSIS	____	____
OTHER	____	____

Please list other break downs used by you or attach record blank.

10. Do your accident reports include the specific working conditions/ environment?

	YES	NO
HEIGHT	____	____
SLIPPERY PLATFORM	____	____
RAIN	____	____
PROTECTIVE CLOTHING	____	____
ILLUMINATION	____	____
NOISE LEVEL	____	____
OTHER	____	____

If other, please list or attach report blank.

11. Is there any recording of unsafe acts which did not result in lost time, require medical treatment, damage equipment, or cause delays in time?

YES _____ NO _____

If yes, please state method of recording and collecting data.

If yes above, how long have you been collecting data on unsafe acts? _____________________

12. Over what period of time has industrial accident data been collected?

BEGINNING YEAR ________

ENDING YEAR ___________

13. Do you use the "Standard Industrial Classification 1957 Revision" for your break down of industry classification?

YES _____ NO _____

If no, what industrial classification system are you using?

14. Are your accident data collected as a result of laws or regulations?

YES _____ NO _____

If yes, please list:

15. Do you or any associated agency perform detailed investigations of the causes of accidents?

YES _____ NO _____

Or, do you accept the reported cause of the accident?

YES _____ NO _____

16. Do you distribute or publish special or regular reports which are available?

YES _____ NO _____

If yes, please include a listing of these publications:

Thank you for participating in this survey. Please feel free to append further comment, or to expand on particular responses.

APPENDIX C

ANNOTATED BIBLIOGRAPHY

Accident publications are numerous; however much of it is concerned with theoretical causes rather than being specifically factual. Of the factual, or statistical, data the most abundant source of publications is the U.S. Department of Labor.

The relevant articles noted are organized into three main areas: accident statistics, human variables encountered in accidents, and prediction and prevention of accidents. Statistical data annotated, pertains to general industry, specific industries and their associated occupations and intrastate industries. The method of organization of most of these statistics is based on the U.S. Department of Labor Standards, and therefore varies little in amount of information contained in each article.

Part 1

WORK INJURY STATISTICS BY INDUSTRY

The majority of injury statistics for various industries is compiled by the U.S. Department of Labor, either in the Bureau of Labor Statistics Bulletins, or in their publication, *Monthly Labor Review*. The data from the Department of Labor is the most inclusive in terms of the number of different industries compiled; manufacturing as well as non-manufacturing industries such as mining, construction, and utilities are compared in each publication.

Injury statistics in this grouping are generally comprised of frequency and severity rates by industry for a particular time period. Because a given industry is composed of a diversity of processes, functions, and occupations within each process, it is difficult to compare these gross statistics of frequency and severity rates over dissimilar industries and achieve any meaningful or predictive results.

Barker, R. S., "Work Injuries in the U.S., 1955", <u>Monthly Labor Review</u>, 80:62-6, Ja. 1957.

Injury rates for manufacturing and non-manufacturing industries are compiled for 1955. Manufacturing industries are classified as to product grouping and non-manufacturing industries are divided as to the function of the industry. Approximately 75 industry groupings are considered in this article as well as the number of employees for each.

Injury-frequency rates are compared with the previous year's, 1954; severity rates, average days of disability per case for permanent partial impairment as well as temporary total disability are given along with the percent of disabling injuries resulting in death, permanent impairment and temporary total disability for each industry classification.

Barker, R. S., and Smith, F. M., "Work Injuries in the U.S., 1956", <u>Monthly Labor Review</u>, 81:54-8, Ja. 1958.

Injury-frequency rates are compiled by allied manufacturing industry groupings, such as food and kindred products, and rubber products. In total about 140 industries are included in this data for years 1955 through 1957. Each year is considered by quarterly frequency rate, with an annual average of injury-frequency rate for 1955 and 1956.

Machisak, John, "Work Injuries in U.S., 1954", <u>Monthly Labor Review</u>, 79:58-62, Ja. 1956.

Injury rates for manufacturing and non-manufacturing industries are compiled for 1954. Manufacturing industries are classified as to product grouping and non-manufacturing industries are divided as to the function of the industry. Approximately 75 industry groupings are considered in this article as well as the number of units reporting in each industry and the total number of employees for each.

Injury frequency rates are compared with the previous year's, 1953; severity rates, average days of disability per case for permanent partial impairment as well as temporary total disability are given along with the percent of disabling injuries resulting in death, permanent impairment and temporary total disability for each industry classification.

<u>Monthly Labor Review</u>, "Injury Rates, by Industry, 1958, and Injury-Frequency Rates, 1957", 1959 Statistical Supplement, pgs. 72-76

The industries compiled in this article are divided into manufacturing and non-manufacturing areas. The manufacturing industries are further divided into groupings of kindred products, such as lumber and wood products, chemicals, and apparel. The non-manufacturing industries are grouped as to related function or product, i.e., mining, wholesale trade, and utilities.

Data included in this section for 1958, are the number of reporting units and the number of employees for each industry as well as frequency and severity rate. Included in this section is frequency rate for 1957. Also, for 1958, is the average days of disability per case for permanent partial disability and temporary total disability as well as percent of disabling injuries resulting in death, permanent impairment and temporary total disability.

Monthly Labor Review, "Injury Rates in Manufacturing, 1955", 79: 183-6, Feb. 1956.

Injury-frequency rates are compiled by allied manufacturing industry groupings, such as food and kindred products, paper products, and chemacals. In total about 140 industries are included in this data. 1954 and 1955 frequency rates are considered by quarter, with 1955 third quarter data by each month, in addition to an annual average frequency rate for 1954.

Monthly Labor Review, "Work Injuries: Injury-Frequency Rates for Selected Manufacturing Injuries", 81:131-2, Ja. 1958.

Injury rates for manufacturing and non-manufacturing industries are compiled for 1956. Manufacturing industries are classified as to product grouping and non-manufacturing industries are divided as to the function of the industry. Approximately 75 industry groupings are considered in this article as well as the number of units reporting in each industry and the total number of employees for each.

Injury-frequency rates are compared with the previous years, 1955; severity rates, average days of disability per case for permanent partial impairment as well as temporary total disability are given along with the percent of disabling injuries resulting in death, permanent impairment and temporary total disability for each industry classification.

Monthly Labor Review, "Work Injuries: Tables", 79:893-4, July 1956.

Injury-frequency rates are compiled by allied manufacturing industry groupings, such as food and kindred products, textile products, and transportation equipment. In total about 140 manufacturing industries are included in this data for years 1954 and 1955, and first quarter 1956. Years, 1955 and 1954 are considered by quarter with an annual average frequency rate for each. The first quarter, 1956, frequency rate is included and is also considered separately by the three months of the quarter.

<u>Monthly Labor Review</u>, "Work Injury Rates, 1958 to 1961, Revised", 1963 Statistical Supplement, pgs. 53-64.

The industries compiled in this report are divided into manufacturing and non-manufacturing areas. The manufacturing industries are further divided into groupings of kindred products, such as lumber and wood products, chemicals, and apparel. The non-manufacturing industries are grouped as to related function or product, i.e., mining, wholesale trade, and services.

Data included is for years 1958 through 1961, inclusive, and is comprised of injury-frequency rates, injury severity rates, and the average days of disability per case.

<u>National Safety Council</u>, "Accident Facts, 1969 edition", Chicago, Illinois, 1969, pg. 96.

This publication covers all accidents, industrial as well as non-industrial, for the one year period, 1968.

Industrial, or work, injuries are covered as to death rates, frequency and severity rates for broad industry groupings, such as manufacture, service and agriculture. A comparison to the 1967 deaths and death rate is computed as a percent change.

Total time lost from accidents, in days, is tabulated for injured as well as non-injured personnel and the total costs of these accidents are delineated for visible and other expenses and the cost per worker to industry. Cost is also computed as the total cost per source or cause of the injury--falling and machinery.

<u>National Safety Council</u>, "Work Injury Rates, 1969 edition", Chicago, Illinois, 1969, pg. 63.

This pamphlet includes the 1968 injury rates, classified as to major industry groupings, as reported to the National Safety Council. A comparison of these rates is made to the average frequency & severity rates for years 1966 and 1967.

Disabling injuries, temporary total and permanent partial disabilities are discussed by industry while specific industry rates (aircraft manufacturing, petroleum drilling) of frequency and severity are compared for 1966 through 1968 as well as the number of units in each industry reporting to the National Safety Council Surveys.

Included is historical accident data (1941-1968) by industry covering frequency & severity rates and the average time charges per incident.

News, "Manufacturing Injury Rates Stayed at a High Level in 1968", U.S. Department of Labor, Bureau of Labor Statistics, Nov. 5, 1969.

Work injury frequency rates for 1968 were compared to those of 1967 for 21 major industry groups in manufacturing, and 7 major industry groups involved in non-manufacturing operations. Included in this article is the injury severity rate for these industries and the average days of disability per injury for the year 1968.

The trend in work injury frequency rates from 1958 to 1968 is presented graphically for a comparison of the selected industry divisions and groups: coal mining, contract construction, manufacturing, trade, and the Federal Government.

U. S. Department of Health, National Health Survey Series, "Persons Injured While at Work, U.S., 1959-1961", Jan. 1963, pub. 584-B41.

This publication presents a series of tables as analysis of the distribution of industrial accidents among people and causes over a period of 3 years, from 1959 to 1961. Data is based on a survey compiled through household interviews with the civilian, non-institutional population. Rates of accidents are the average annual number of persons injured, including only currently employed persons with work injuries involving one or more days of restricted activity, or medical attention.

Included in the tables are the type of accident (falls, struck by moving object) by place of accident, industrial place or "other": and the average number of accidents and disability days for groups based on sex, age and educational level of the victim, versus his area of residence: urban, rural farm and non-farm.

U. S. Department of Labor, Bureau of Labor Statistics, "Injury Rates by Industry, 1966-1967", Bulletin No. 360.

The industries compiled in this bulletin are divided into manufacturing and non-manufacturing areas. The manufacturing industries are further divided into groups of kindred products, such as lumber and wood, chemicals, and apparel. The non-manufacturing industries are grouped as to related function or product, i.e., mining and wholesale trade.

Data included in this section, for years 1966 to 1967, is comprised of frequency and severity rates, average days of disability per injury and the percentage of disabling injuries resulting in death, permanent impairment or temporary total disability.

A second table is a compilation of work injury frequency and severity rates for each of the manufacturing product groups for 1966 and 1967, by selected states.

U. S. Department of Labor, Bureau of Labor Statistics, "Injury Rates by Industry 1964-1965", Bulletin NO. 342.

The industries compiled in this bulletin are divided into manufacturing and non-manufacturing areas. The manufacturing industries are further divided into groupings of kindred products, such as lumber and wood, chemicals, and apparel. The non-manufacturing industries are grouped as to related function or product, i.e., mining, wholesale trade, and service industries.

Data ancluded in this section, for years 1964 and 1965, is comprised of frequency and severity rates, average days of disability per injury for permanent partial disability and temporary total disability cases, and the percentage of disabling injuries resulting in death, permanent impairment or temporary total disability.

Occupation Study, 1967, Society of Actuaries, Chicago, Illinois, Dec. 1967, pp. 89.

This is an intercompany mortality study by type of occupation of individual life insurance policies issued to males in 1949 through 1963. This study was limited primarily to occupations that are currently considered substandard by most insurance companies for either life insurance or accidental death benefits. However, certain other occupations where there was some reason to expect mortality somewhat above that for standard risks as a whole were also included. The main observation period for this study is the ten year period between 1954 and 1964.

Rates are given for industry groups, mortality by issue age, policy year and cause of death as well as by occupational group within industries, and cause of death.

Mortality rates are considered as a mortality ratio of actual versus expected deaths. This study included only deaths by industry or occupation, not necessarily accidental deaths, for most deaths cited are natural disease inflicted.

<u>Safety Maintenance</u>, "How Does your Plant Safety Rate"? v. 118, n.4, Oct. 1959, pp. 14-15.

Included in this article is a table of the frequency and severity rates of injuries for 40 industry classifications. The data is based on the 1958 injury rates as reported by the National Safety Council. The frequency rates are for disabling injuries per million man-hours and the severity rates represent the time charges, in days, lost per million man-hours worked. In addition to these, is a comparison to the 1957 injury rates considered as a percent change from 1957.

Part 2

ACCIDENT STATISTICS BY INDUSTRY AND OCCUPATION

The majority of accident data within the various individua industries and the occupational areas employed by them are compiled by the Dept. of Labor. Infrequent publications of the frequency and severity rates, and major causes of these industrial accidents appear as Bureau of Labor Statistics bulletins and excerpts of these in the various trade journal.

These publications, generally out of date by the time they're published, contain only statistics and explanations of them; no conclusions are drawn, no theorizing as to preventitive measures. In fact, the categories and classifications of accident data and the method of reporting these has not changed substantially since World War II.

Included in this section are articles and pamphlets containing statistical accident information for manufacturing and non-manufacturing industries.

Agriculture and Related Industries

Very little accident data is available on agriculture and its related industries. Many reasons exist for this shortage; in the case of farms, many are small and so isolated that only the most severe injuries are treated by a physician. Agriculturally related industries, such as canning, are generally small seasonal operations employing only part-time or temporary help and therefore are not concerned with accident prevented over a long term or even yearly basis. Thus, little accident data is gathered in these industries.

McCormack, G. R., "Injury Rates in the Canning and Preserving Industry, 1952", Monthly Labor Review 77:540-4, May 1954.

This data is compiled by the U. S. Bureau of Labor Statistics and is based on the reporting of 1,802 cooperating canning and preserving establishments employing 132,517 workers during 1952.

Included in this article are tables detailing the frequency and severity rates as well as the average number of days lost per disabling injury. These rates are classified as to division of the industry (by product) and by department over the total industry.

McCormack, G. R., "Injury Rates in the Fluid Milk Industry, 1952", Monthly Labor Review, 76:1295-9, Dec. 1953.

This data is compiled by the U. S. Bureau of Labor Statistics and is based on a survey of 3,565 milk establishments employing 101,105 workers during 1952.

A table is included detailing the frequency and severity rates of disabling injuries, and the number of days lost per incident. This data is classified as to the type of trade of the various establishments (wholesale, retail dealers or stores, and integrated wholesale and retail) and to the various departments within the total industry.

Construction Industry

The construction industry with its various associated occupations, is surely one of the most hazardous industries in terms of the number of disabling injuries and deaths yearly. However injurious it may be, little detailed data has been gathered for these occupations; the majority available is compiled by the U.S. Department of Labor, while other sources usually draw from this.

Generally not mentioned in any of the articles, including the Department of Labor, is the source or sources of their information, whether contracting companies or unions. If the data is derived from unions, all those non-union workers in the construction industry are therefore not taken into account. This entails an even larger void in the data than appears to exist by merely an inadequate amount of it.

Construction Review, "Work Injuries in Construction", 12:6, June 1966.

Various tables are included in this article concerning the frequency and severity rates of disabling injuries for the construction industry covering the period 1958 through 1963.

Construction Review, "Work Injuries in Contract Construction 1957", 5:7-8, Jan. 1959.

Data included in this article is tabulated as to the frequency and severity rates of disabling injuries for the various types of contractors (general, highway, plumbing) in the construction industry for the year 1957. Also included is the percent of the total disabling injuries resulting in death, permanent impairment, or temporary total disability.

Construction Review, "Work Injuries in Contract Construction, 1956", 3:4-5, October 1957.

The information in this article was compiled by the U.S. Department of Labor, Bureau of Labor Statistics. It includes various tables concerning the frequency and severity rates and the average number of days disability per case for each type of contractor for the construction industry covering years 1955 and 1956.

Engineering News, "Construction's Accident Record, Selected Years 1930-1957", 161:21, October 30, 1958.

A table is presented of the construction industry's accident record for 12 selected years from the period 1930 through 1957. Included in this table is the frequency rate, the number of disabling injuries per one million man-hours, and the severity rate, days lost per one-million man-hours, for each of these 12 years.

Engineering News, "Fewer Work Injuries in 1957" 161:46, Dec. 25, 1958.

Included in this article is a table of injury frequency and severity rates, and the average number of days lost per disability detailed by work craft (plumbers, contractors) for the years 1956 and 1957.

Machisak, John, "Work Injuries in Contract Construction, 1948-1954", *Construction Review*, pp. 4-9, March 1956.

The information in this article was compiled by the U.S. Department of Labor; Bureau of Labor Statistics. It

includes various tables concerning the frequency and severity rates and days lost per different type of disability for the contract construction industry covering the years 1948 through 1954.

McElroy, F. S. and McCormack, G. R., "Injury Rates in Construction Occupations, 1948 (U.S.)", Monthly Labor Review, 70:387-9, April 1950.

Industrial injury rates are gathered for 16,321 construction companies for the year 1948. Rates are arranged by occupation, such as glaziers, roofers, and painters, with the number of establishments reporting for each and the number of employee hours worked in each of the occupations. Disabling injury frequency rates are reported for death or permanent total disability, permanent partial disability and temporary total disability. Severity rates are reported as the number of days lost per disabling injury or per temporary total disability.

Safety Maintenance, "Falls by Carpenters", 137:24, Feb. 1969.

The most prominent cause of accidents by carpenters on construction jobs is slips and falls, which accounted for 1 in 3 lost time injuries studied. The likelihood of this type of injury increases with the age of the carpenter.

One in four of the cases of disabli g falls resulted from falls from structures via unsecured ladders, unnailed planking or unbraced scaffolds.

The second prominent injury inducing activity was the handling or use of tools or machinery, such as power hand saws or table saws.

Shaw, Christopher, Capt., "The Problem of Industrial Safety", Industrial Medicine and Surgery, 27:480-2, Sept. 1958.

The article is an analysis of 403 consecutive lost time accidents during a six year-six month period from January 1949 through June 1955, at the U.S. Navy shipyard at Philadelphia and is representative of occupations involved in the construction and repair of naval vessels.

These accidents are detailed and tabulated as to severity, part of body injured and type of accident, agency involved and unsafe act committed.

U. S. Department of Labor, Bureau of Labor Statistics, "Fatal and Injury Accidents on Federal Aid and Other Highway Systems", Bulletin No. 296, 1969.

This bulletin covers the accidents of all occupations involved in street & highway construction including professional workers, managers and officials, as well as clerical workers for the year 1961.

Each occupational group is divided in specific occupations (bricklayers, inspectors, road-roller operators) for further analysis as to type of accident, geographic region, and the nature of the injury and combinations of these. Data is given as the total number of disabling injuries and the percent of each group to the total number of disabling injuries.

U. S. Department of Labor, Bureau of Labor Statistics, "Work Injury Rates in Heavy Construction", Bulletin No. 318.

This bulletin covers the accidents of all occupations involved in the heavy construction industry including professional workers, managers and officials, as well as clerical workers for the year 1961.

Each occupational group is divided into specific occupations (bulldozer operators, piledrivers, pipe layers) for further analysis as to type of accident, geographic region, and the nature of the injury and combinations of these. Data is given as the total number of disabling injuries for each classification and the percent of each group to the total number of disabling injuries.

Electric Power Industry

The compilation and publication of the statistics contained in this section were undertaken by the Edison Electric Institute, Accident Prevention Committee. These articles were designed to assist the electric utility companies in their efforts to decrease the number of fatalities occurring during each year.

Bremner, W. C., "An Analysis of Fatal Accidents in the Electric Light and Power Industry in 1963," _Edison Electric Institute Bulletin_, August 1964, pg. 231-5.

A detailed account of 81 of the 87 fatalities of electric utility employees in 1963 is supplied in this article. Only half of these fatalities were caused by electric shock or burn, the remainder caused by falls, struck by, crushed, or motor vehicles.

An historical record of 23 years fatalities is noted as to cause for the period covering 1941 to 1963 inclusive. Comparison tables are supplied in an analysis of the age of the victim, years experience prior to the incident, cause of accident and protective equipment required but not used by the victim at the time of the accident.

Bremner, W. C., "An Analysis of Fatal Accidents in the Electric Light and Power Industry in 1962", _Edison Electric Institute Bulletin_, August 1963, pg. 277-281.

A detailed account of 72 of the 79 fatalities of electric utility employees in 1962 is supplied in this article. Only half of those fatalities were caused by electric shock or burn, the remainder caused by falls, caught in, motor vehicles, aerial baskets, struck by, and burned by fire or acid.

An historical record of 22 years' fatalities is noted as to cause for the period covering 1941 through 1962 inclusive.

Comparison tables are supplied in an analysis of the age of the victim, years experience prior to the incident, cause of accident and protective equipment required but not used by the victim at the time of the accident.

Bremner, W. C., "An Analysis of Fatal Accidents in the Electric Light and Power Industry in 1961", _Edison Electric Institute Bulletin_, May 1962, pg. 143-147.

A detailed account of 81 of the 85 fatalities of electric utility employees in 1961 is supplied in this article. 57 of those fatalities were caused by electric shock or burn, the remainder caused by falls, motor vehicle accidents, struck by, crushed and drowning.

An historical record of 21 years' fatalities is noted as to cause for the period covering 1941 to 1961 inclusive.

Comparison tables are supplied in an analysis of the age of the victim, years experience prior to the incident, cause of accident and protective equipment required but not used by the victim at the time of the accident.

Bremner, W. C., "An Analysis of Fatal Accidents in the Electric Light and Power Industry in 1960", Edison Electric Institute Bulletin, July-August 1961, pg. 275-279.

A detailed account of the 105 fatalities of electric utility employees in 1960 is supplied in this article. 80 of these fatalities were caused by electric shock and burn, the remainder caused by motor vehicle accidents, falls, crushed, and struck by.

An historical record of 10 years' electric shock and burn fatalities are noted as to part of body contacted (for line work on poles), or activity at time of accident.

Comparison tables are supplied in an anlysis of the age of the victim, years experience prior to the incident, and cause of accident.

Stewart, D. C., "Fatal Accidents in the Electric Power and Light Industry", Edison Electric Institute Bulletin, 19:2, Feb. 1951, pg. 47.

A detailed account of 176 fatalities of electric utility employees in 1949 is supplied in this article. The cause of accident (shock, falls, motor vehicle) and part of body injured and circumstances of the accident are noted.

An historical record of 9 years' fatalities are noted as to cause for the period covering 1941 through 1949.

Young, S. H., "Analysis of Fatal Accidents in the Electric Light and Power Industry in 1959", Edison Electric Institute Bulletin

A detailed account of the 100 fatalities of electric utility employees in 1959 is supplied in this article. 59% of the total fatalities were caused by electric shock and burn, the remainder caused by falls, motor vehicle accidents, struck by, and burned.

An historical record 19 years' fatalities is noted as to cause for the period covering 1941 to 1959 inclusive.

Comparison tables are supplied in an analysis of the age of the victim, years experience prior to the incident, cause of accident and protective equipment required but not used by the victim at the time of the accident.

Young, S. H., "Analysis of Fatal Accidents in Electric Light and Power Industry in 1958", Edison Electric Institute Bulletin, 28:7, July-August 1959, pg.275.

A detailed account of the fatalities of electric utility employees in 1958 is supplied in this article. Most of these fatalities were caused by electric shock and burn, the remainder by various causes such as falls and motor vehicle accidents.

Comparison tables are supplied in an analysis of the age of the victim, years experience prior to the incident.

Manufacturing Industries

The U.S. Department of Labor categorizes the manufacturing industry into 22 major areas based on product similarity, i.e., wood products. Within each product category is a more specific grouping of several industries, again based on similarity of the end product; these areas total over 150 separate manufacturing industries and comprise several hundred companies each. Generally, accident statistics for the manufacturing industries are given as a whole, without thought to the different operations comprising this large group of industries.

The Bureau of Labor Statistics is the only major source of accident information for the separate manufacturing areas. However, in depth studies of these various allied industries is lacking. A few publications on these separate industries are available and are annotated below; however, there seems to be no published basis of selection of the industries to be studied and very few of these studies have been conducted within the past 10 years.

American Pulpwood Association, "Analysis of Accident Reports on Pulpwood Operations of APA Industry Members in Southern U.S., 1968", Dec. 1, 1969, pp. 9.

The results shown in this survey are based on reports from 21 member companies in the Southeastern and Southwestern Technical Divisions of the American Pulpwood Association Represented is a total of twelve and 1/2 million man-hours worked in the woodlands operations of thirty-one mill areas.

In the tables of this report, each department is taken in turn and analyzed as to injury cases, agency, nature of the injury and part of the body injured. Since administration in general had no injuries to report, only the other areas of pulpwood procurement, forest management, company harvest operations and others are analyzed.

It is indicated that most of the injuries could be prevented by protective equipment and safe work practices.

McCormack, G. R., "Injury Rate Variations in the Boiler-Shop Products Industry", _Monthly Labor Review_, 76:621-4, June 1953.

A wide variety of plants are included in the boiler-shop products industry. These plants differ in kind of product manufactured, in size of plant, and in type of operation. Each of these characteristics exerts a direct influence on the level of injury rates within any plant.

To permit more analytical comparisons, the Bureau of Labor Statistics, in 1951 conducted a survey of these various plants. This article is the result of that survey. Included are tables of the frequency and severity rates of disabling injuries in the boiler shop products industry, classified by type of plant and by operations for the year 1951.

McElroy, F. S. and McCormack, G. R., "Injuries and Accidents in Fertilizer Manufacturing", Monthly Labor Review, 67:606-11, Dec. 1948.

This article analyzes the 1946 accident records of 185 fertilizer plants employing nearly 15,000 during this period. All disabling as well as other injuries requiring treatment by a physician are included in the data covering 2,532 injury cases reported to the U.S. Department of Labor, Bureau of Labor Statistics.

Graphs are presented in the tabulation of the major agencies involved in these accidents, the major types of unsafe working conditions leading to these incidents, and the major type of unsafe act triggering the accident.

McElroy, F. S. and McCormack, G. R., "Textile Dyeing and Finishing: Work Injuries in 1945", Monthly Labor Review, 67:20-5, July 1948.

This article analyzes the 1945 accident records of selected companies in the textile dyeing and finishing industry, reporting to the U.S. Department of Labor, Bureau of Labor Statistics. The plants employed a total of 64,000 workers accumulating 139 million hours during the one year period. Only disabling injuries are considered in the data covering 2,876 injuries reported.
Graphs are presented in the tabulation of the injury frequency rate in the various departments of this industry. Injury rates are considered as a percentage of the total disabling injuries in the tabulation of the major types of unsafe working conditions involved, and the major types of unsafe acts committed.

McElroy, F. S. and McCormack, G. R., "Work Injuries in Pulp and Paper Manufacturing, 1939-1949", _Monthly Labor Review_, 71:338-42, Sept. 1950.

Industrial injury rates are presented for the pulp and paper manufacturing industry that includes all the various departments involved in the operations of paper paperboard and pulp mills.

Injúry rates for a typical year, 1948, are classified by product and by department, giving the frequency rate of incidents, and the number of disabling injuries resulting in death or permanent total disability, permanent partial disability and temporary total disability.

U.S. Department of Labor, Bureau of Labor Statistics, "Work Injuries and Accident Causes in Concrete Brick and Block Industry", Bulletin No. 317.

This pamphlet analyzes the 1957 accident records of selected companies in the concrete brick and block industry, reporting to the U.S. Department of Labor, Bureau of Labor Statistics. The 255 plants surveyed had a total of 907 disabling injury accidents.

Graphs and tables are presented in the tabulation of the injury frequency rate in the various occupations employed in this industry. Injury rates are considered as a percentage of the total disabling injuries in the tabulation of the data. Included in the data are analyses of the unsafe act committed, type of accident, source of injury and hazardous working condition leading to the incident.

The results of this analysis caused the industry to direct their accident prevention programs to handling activities, delineating safe operating procedures, providing adequate guarding on power equipment and requiring safety footwear.

U.S. Department of Labor, Bureau of Labor Statistics, "Work Injuries and Accident Causes in Sawmills", Bulletin No. 249.

This pamphlet is the result of a study to obtain comprehensive information about the occurrence of accidents in sawmills undertaken by the Department of Labor.
Various tables and graphs are included delineating the frequencies and percentage of the total disabling injuries incurred by: the activity of the injuried, the types of accidents, unsafe act committed and the resultant type of injury.

Other Industries

Included in this section are smaller industries, those not as widespread as the construction or manufacturing industries.

Each of the industries dealt with has their own unique operations and environments, and therefore unique hazards. For instance, the Atomic Energy Commission sites have the danger of radiation, whereas the aircraft ground crews have machinery and engine hazards. However, most injuries encountered are similar to those of other industries, differing only in details.

Eschenback, A. E., Major, "Injuries and Accidents at a Missile Test Center", Journal of Occupational Medicine, 4:1, pp. 16-19, Jan. 1962.

The purpose of this survey was to provide basic and objective information concerning occupational health problems encountered in modern missle operations.

Injuries are placed in one of two categories. Missile operations or industrial support. Accidents are classified as to type of injury, body part injured, time of accident and hours worked prior to injury.

The data were collected from two large samples at the Air Force Missile Test Center, Cape Canaveral, Florida. A statistically significant relationship was found between missile operations and industrial support activities with respect to accident types, injury types, body parts injured, time of injury, and the number of hours worked on shift prior to injury. The data obtained were found to be consistent from the first one-year (1958) sample to the second one-year (1959-1960) sample.

Kiefer, N. C., "Office Safety", Journal of Occupational Medicine Vol. 9, No. 11, pp. 560-566, Nov. 1967.

This article is based on an analysis of office accidents which occurred over a period of 5 years, 1962-1966, at the home office of the Equitable Life Assurance Society of the United States. In the 5 years, there were 2079 work accident injuries, of which 336 were disabling, with 2748 days lost from work.

There were 36 disabling accidents incurred during company-sponsored sports and other recreational activities, with 296 lost days. The most common type of accident occurring to office personnel were falls that accounted for 55% of the lost days.

The rate of injury accidents among male office work employees was about the same for their female counterparts. Their rate of disabling injuries was slightly higher, but their rate for total days lost was 2 1/2 - 3 times as high as among female employees.

The disabling accident rate was highest in employees under 20. It dropped in the 20-29 age group, and in most of the 5 study years was lowest at 30-59, with a modest rise at 60-64 years.

Consistently the accident injury rates among employees with less than one year of service was 3-4 times those of employees with 5 or more years of service.

A total of 80% of all the office accidents were caused by unsafe

acts and nearly 75% were judged to be solely the fault of the employee to whom the accident occurred.

McElroy, F. S., and McCormack, G. R., "Work Injuries to Crew Men on Inland Waterway Vessels", Monthly Labor Review, 71:676-80, Dec. 1950.

This data was compiled by the U.S. Bureau of Labor Statistics and is based on the reporting of 4,548 cooperating vessels with accumulated employee hours of 59,182 (in thousands) during the year 1946.

Included in this table are injury frequency and severity rates as well as the number of days lost per disabling injury, classified as to geographic location of the vessel and occupation and department of its injured crewmen.

McFarland, R. A., "Prevention of Accidents in Aviation Ground Operations", Shell Aviation News, n. 216, pp. 14, Jan. 1956.

Included in this article is data relating the accident rates of air transport personnel employed at air transport companies. This data, covering a 12 year period from 1942 through 1954, is classified as to employee groups and recounts the number of injuries requiring first-aid and the place of the accident.

U. S. Atomic Energy Commission, "Operational Accidents and Radiation Exposure in U.S. AEC, 1943-67", Item No. 1051, 1969.

This article analyzes the 25 year accident records, from 1943-1967, for 16,978 lost time injuries and 276 deaths at U. S. Atomic Energy Commission Sites.

Of these injuries and deaths, approximately half occurred during actual AEC operations, the majority of the remainder occurring during construction operations.

Data is analyzed as to injury-frequency and severity rates, body part injured, and property damage incurred from these and other accidents. A brief description of each fatality is included recounting date and place of incident as well as the cause and type of injury leading to death.

U. S. Dept. of Labor, Bureau of Labor Statistics, "Injuries and Accident Causes in Warehousing Operation," Bulletin No. 1174, Jan. 1955.

This pamphlet analyzes the 1950 accident records of 2,695 warehouses reporting this information to the Dept. of Labor. The warehouses had a combined total of 31,956 and disabling

accidents totaling 1,604 during the one year survey.

Graphs & tables are presented in the tabulation of the injury frequency rate and severity in the various departments, occupations, and type of warehouse (by products stored).

Included are analyses of the nature of the injury, part of body, accident type, agency of injury and combinations of these.

Service Industries

The various service industries, unlike manufacturing, have unique environments and associated hazards. For instance, employees of hospitals and lunchrooms have to deal with extremely sharp tools and very hot or cold substances; but hospital employees, alone, have to move and manipulate immobile people and, in the process, have accidents.

The service industries generally employ a preponderance of women although the auxiliary agencies of these industries, repair departments and general upkeep of tools and machinery, are predominantly handled by men and differ only slightly from similar activities in other industries.

Mammen, Mr., "The Need for Employee Health Services in Hospitals", Archives Environmental Health, 9:750-7, Dec. 1964.

A compilation was made of the injuries and illnesses for each month of the biennium of July, 1959 through June, 1961 at a general hospital. The data were assembled as to department and/or job classification, diagnosis of the injury or illness and cause of the injury or illness.

The need for employee health services at this hospital was demonstrated by the environmental health hazards present and the accident frequency rate, based on 71 lost-time accidents over a one year period.

McCormack, George, "Work Injury Rates in Hospitals, 1953", Monthly Labor Review, 79:684-7, June 1956.

This data is compiled by the U.S. Bureau of Labor Statistics and is based on the reporting of 4,680 cooperating hospitals employing 837,552 workers during the year 1953.

Included in this article are tables, detailing the number of disabling injuries resulting in death or permanent total disability permanent partial disability and temporary total disability, and the injury frequency rate for each. Severity rate and average number of days lost or charged per incident for each of the four types of hospitals: general, mental, tuberculosis and special. The work injury frequency rate is also given by department and by division.

U. S. Department of Labor, Bureau of Labor Statistics, "Work Injuries and Accident Causes in Hospitals", Bulletin No. 341.

This pamphlet analyzes the 1963 accident records of selected hospitals reporting this information to the U.S. Department of Labor. These hospitals had a combined total of 31,148 disabling injuries during the one year period of the survey.

Graphs and tables are presented in the tabulation of the injury frequency rate in the various occupations employed in this industry. Injury rates are considered as a percentage of the total disabling injuries in the tabulation of the data. Included are analyses of the unsafe act committed, type of accident, source of injury and hazardous working conditions leading to the incident.

U. S. Department of Labor, Bureau of Labor Statistics, "Work Injuries and Accident Causes in Hotels", Bulletin No. 329, July 1967.

This pamphlet analyzes the 1960 accident records of selected hotels reporting this information to the Bureau of Labor Statistics. These hotels had a combined total of 3,965 disabling injuries during the one year period of the survey.

Graphs & tables are presented in the tabulation of the injury frequency rate in the various occupations employed in this industry. Injury rates are considered as a percentage of the total disabling injuries in the tabulation of the data. Included are analyses of the unsafe act committed, type of accident, and source of injury and hazardous working condition leading to the incident.

It was concluded that a lack of perceived danger in hotel activities led to laxness in the employees' use of safe procedures.

U. S. Department of Labor, Bureau of Labor Statistics, "Work Injuries and Accident Causes in Lunchrooms", Bulletin No. 316.

This pamphlet analyzes the 1958 accident records of 210 school lunchrooms reporting this information to the U. S. Department of Labor. These lunchrooms had a combined total of 1,794 disabling injuries during the one year period of the survey.

Graphs and tables are presented in the tabulation of the injury frequency rate in the various occupations employed in this industry. Injury rates are considered as a percentage of the total disabling injuries in the tabulation of the data. Included are analyses of the unsafe act committed, type of accident, source of injury and hazardous working condition leading to the incident.

Part 3

INDUSTRIAL ACCIDENT STATISTICS BY STATE

Included in this section are accident statistic publications from 13 states responding to a request for such information.

In most cases, the states rely on the U. S. Department of Labor, Bureau of Labor Statistics for their data and aid in the compilation of it. Because the states haven't the resources of the federal government, their publications fall short of those of the U. S. Bureau of Labor Statistics. These states use the Federal Standards for compilation of accident statistics, the codes, causes and general method of analysis; therefore the states' publications have the same shortcomings as the Bureau of Labor Statistics and, because of their lack of resources, less data and analysis than the federal agency.

ALABAMA -

Alabama Department of Industrial Relations, Division of Safety & Inspection, "Alabama Work Injuries 1969", Birmingham, Alabama, pp. 26.

This is a cooperative work injury survey taken in conjunction with the U. S. Department of Labor, Bureau of Labor Statistics, for the year 1969. The survey covers 4,700 firms employing approximately 295,000 persons.

Industries are grouped into categories of related areas, i.e., manufacturing, trade and services. Within each of these general areas, industries are grouped as to kindred product or service. For each of these Alabama industries, total man hours, total injuries, injury frequency rate, and injury severity rate are given for the year 1969.

ARIZONA -

State of Arizona, "57th Annual Report of the State Mine Inspector for the Year Ending 30 November 1968", Phoenix, Arizona.

In this publication only those mine accidents are considered that caused a fatality or lost time of more than fourteen days. These are analyzed as to date of mishap, number of persons killed or injured (resulting in more than 14 days absence), cause of death or disability (fall of rock, overturned truck), and name and company of mine at which the accident occurred.

State of Arizona, "56th Annual Report of the State Mine Inspector for Year Ending 30 November 1967, Phoenix, Arizona.

In this publication only those mine accidents are considered that caused a fatality or lost time of more than 14 days. These are analyzed as to date of mishap, number of persons killed or injured (resulting in more than 14 absences), cause of death or disability (fall of rock, overturned truck) and name and company of mine at which the accident occurred.

ARKANSAS -

Arkansas Department of Labor, "Arkansas Work Injuries 1968, Selected Industry Divisions", Little Rock, Arkansas, July 1969.

This report presents data on work injuries in Arkansas for the calendar year, 1968 - the results of the second annual state-wide study conducted by the Arkansas Department of Labor in cooperation with the U. S. Department of Labor, Bureau of Labor Statistics.

Frequency and severity rates are given for the various product classifications of the manufacturing industries engaged in Arkansas.

CALIFOR IA -

Powers, Jean E., "Accident Prevention Statistics - A State Program in Action", at Interstate Conference on Labor Statistics, June 26, 1963, San Francisco, California.

This paper details the history and present technique used in the acquisition, compilation and publication of California industrial accident statistics.

These statistics are based on the employer's reports of these accidents forwarded to the California Division of Labor Statistics and Research.

Physician's reports of these accidents are also accumulated, but not used in the published work injury statistics; instead these are used in the compilation of data on occupational diseases.

Publication of accident statistics take the form of monthly and quarterly reports, annual reports and special reports, as well as in informal answers to specific requests by industry and other agencies.

State of California Department of Industrial Relations, Division of Labor Statistics and Research, "California Work Injuries 1968", San Francisco, California, Sept. 1969, pp. 56.

This report is based on information gathered on industries covered by the California Workmen's Compensation Act and excludes data on maritime workers, Federal employees and railroad workers engaged in interstate commerce.

Industries are grouped into categories of related areas, i.e., manufacturing, construction, and services. Within each of these areas, industries are grouped as to kindred product or service. The 204,559 lost time injuries of these industries in 1968 are analyzed as to cause, accident type, agency, part of body injured and combinations of these. Also included are summaries of typical fatalities, organized by cause of death.

State of California Human Relations Agency, Department of Industrial Relations, "Electrical Work Injuries in California, 1968", Division of Labor Statistics and Research, San Francisco, Calif., Nov. 1969, pp. 28.

Electrical work injuries in California are analyzed as to type and part of the equipment causing the damage and unsafe mechanical or physical condition.

In addition, descriptions of selected electrical work injuries are given organized by the agency involved for the year, 1968.

State of California Department of Industrial Relations, Division of Labor Statistics and Research, "Rules and Regulations Governing Filing of Reports of Industrial Injuries", Dec. 1951.

Every work injury to an employee which causes disability lasting longer than the day of the injury or which requires medical services other than first aid treatment is posted within five days after the injury on the State of California form "Employer's Report of Industrial Injury". This form is collected by the Department of Industrial Relations, Division of Labor Statistics and Research at San Francisco, California.

The form requests information as to the employer and the nature of the business as well as details of the victims work, age, sex, hours worked and pay. The accident is described as to place, time, where it occurred and cause of accident, machinery associated with the accident, preventative measures and the nature of the victim's injury.

State of California Human Relations Agency, Department of Industrial Relations, Division of Labor Statistics and Research, "Work Injuries in California", March 1970, pp. 24.

This publication notes the work injury trends for the first 9 months of 1969. This covers a total of 165,149 workers who had disabling job connected accidents.

A quarterly statistical summary of disabling work injuries of individual California industry groupings is given for the period Jan. to March, 1969. This summary includes an analysis of those accidents by agency, nature of injury and part of the body injured, and by accident type.

<u>State of California Department of Industrial Relations, Division of Labor Statistics and Research</u>, "Work Injuries to Office Employees, California", San Francisco, California, August 1963.

This study of injuries to office workers was undertaken to reduce the number of injuries through increased awareness of the hazards which exist and the institution of safer office practices.

This study is based upon analysis of more than 3,000 employers' reports filed with the Division of Labor Statistics and Research during a one-year period, 1959, covering disabling work injuries to office employees.

Injuries are classified as to accident type, nature of the injury, agency involved, occupation of the injured, age, sex and job level, and industry, as well as intercomparisons of these.

<u>State of California Department of Industrial Relations, Division of Labor Statistics and Research</u>, "Work Injury Coding Guide", Jan. 1969, pp. 33.

This guide is used in conjunction with California form, Employer's Report of Industrial Injury. It is used in the compilation of data furnished by the employer, to form the basis of the California work injury statistics.

FLORIDA -

<u>Industrial Medicine & Surgery</u>, "Florida Work Injuries", March 1966, pp. 200-4.

Industries are grouped into categories of related areas, i.e., construction, manufacturing, trade and services. Within each of these general areas, industries are grouped as to kindred product or service. For each of these Florida industries, injury frequency rates, average days of disability, and injury severity rates are given for years 1963 and 1964.

HAWAII -

State of Hawaii, Department of Labor and Industrial Relations, "Services to the Working Man in Hawaii", July 1968 - June 1969, pp. 47.

This annual report is focused on the services of the Department of Labor and Industrial Relations to the working man with the major aim being to assist.

Workmen's Compensation provides benefits to work-accident victims and collects significant data on these.

The Industrial Safety Divisions program is designed to preserve the physical well-being of the working man and the public through safety inspections, safety investigations of accidents, education and, training and promotion of safety.

State of Hawaii, Department of Labor and Industrial Relations, "Workmen's Compensation in Hawaii, 1968", Research & Statistics Office, Nov. 1969, pp. 39.

The 32,056 work injuries in 1968 are analyzed in this publication. Injuries are noted as to total number in each of the categories noted and percent distribution of the total accidents. Accidents are analyzed in graphs and tables as to industry, sex, causative agency, part of body injured, type of accident and nature, and amount of time lost due to the injury.

ILLINOIS -

Illinois Department of Labor, Division of Statistics & Research, "Compensable Work Injuries Reported, 1964", Illinois, March 1967.

This report analyzes the compensable work injuries reported under the Workmen's Compensation and Occupational Diseases Act; this includes those injuries resulting in death, permanent impairment or absence from work of more than one week.

The purpose of this report is primarily to focus attention on the incidence and causes of work injuries in industry in order to provide information for their prevention.

Work injuries reported from January through August 1964 were analyzed by the Industrial Commission for 10 items including: place of injury, agency involved, accident type, industry, part of body injured, age and sex.

INDIANA -

State of Indiana Division of Labor, "Indiana Division of Labor Annual Report, Fiscal Year July 1, 1968 - June 30, 1969", August 1969.

The prime and common function of the Division of Inspection and Safety is to improve working conditions throughout the state. This is best done by education of the inspectors so that they will be proficient in their periodical inspections, investigation of accidents and complaints in order to preserve health and safety standards resulting in reduced injuries and lost time.

Complaints are received daily regarding unsafe conditions. These are given priority over routine inspections. All accident cases are investigated immediately and recommendations are made to prevent reoccurrence.

The main function of the Department of Statistics is focused around the work-injury program. Each year data is requested from selected Indiana industries as to the number of disabling work injuries and the resulting man-days lost. From this information is compiled the frequency and severity rates which are of importance in safety studies.

State of Indiana, Division of Labor, "Indiana Division of Labor Annual Report, Fiscal Year July 1, 1967 - June 30, 1968", August 31, 1968.

The conduct of an occupational safety program encompasses such activities as a constant review of the state's safety rules, a periodic check of the codes with the model codes set forth by the U. S. Standards Institute and others. The primary assignment of the Safety Training Department is to promote industrial health and safety through education and training. Relative to this responsibility, the department serves as a consultant to labor organizations and in-plant safety engineers, plans, promotes, and conducts safety training sessions and safety seminars, and distributes safety brochures and other training materials.

State of Indiana, Division of Labor, Department of Statistics, "1968 Work Injury Facts", Indianapolis, Indiana, Oct. 1969.

Injury experience of the major Indiana industry groups is reviewed for the year 1968. Data for this study was collected via the survey method of employers and yielded frequency rates, injury severity rates and average days of disability for these industries. A comparison is made to the United States injury rates.

Indiana Division of Labor, Statistics Department, "Work Injury Facts, 1965".

Injury experience of the major Indiana industry groups: manufacturing, construction, mining and agriculture, is reviewed for the year 1965. Data for this study was collected via the survey method and yielded frequency rates, injury severity rates and average days of disability as well as the number of reporting units and total employees considered.

MAINE -

State of Maine, Department of Labor and Industry, "Maine Industrial Injuries, 1968", Division of Research and Statistics, Bulletin No. 438, Augusta, Maine, August 1969.

This publication is a tabulation of data received in the annual Work Injury Survey. This survey is conducted by the Division of Research & Statistics in cooperation with the U. S. Department of Labor, Bureau of Labor Statistics.

The data extracted from the work injury reports has been summarized and injury frequency and severity rates computed for major and subordinate industries.

State of Maine, Department of Labor and Industry, "Maine Industrial Injuries 1967", Division of Research and Statistics, Bulletin No. 425, Augusta, Maine, August, 1968.

This publication is a tabulation of data received in the annual Work Injury Survey. This survey is conducted by the Division of Research and Statistics in cooperation with the U. S. Department of Labor, Bureau of Labor Statistics.

For the year 1967, 1561 manufacturing firms employing 4 or more persons were surveyed and in non-manufacturing, for the same year, 6168 reports were received.

The data extracted from the work injury reports has been summarized and the injury frequency and severity rates computed for major and subordinate industries.

NEW YORK -

State of New York, Workmen's Compensation Board, "Compensated Cases Closed, 1967", Research & Statistics, Bulletin No. 22, Jan. 1970.
This annaul statistical report presents an analysis of compensated cases closed in 1967. It sets forth the frequency and severity of various types of employment accidents, and the industries in which they occurred. It helps to identify the how, where and why of these injuries and it is hoped that it will assist in promoting safe working conditions and reducing the cost of work injuries.

PENNSYLVANIA -

Pennsylvania Department of Labor and Industry, Bureau of Research and Statistics, "Compensable Work Injuries in Pennsylvania, 1968", Harrisburg, Penn., November 1969.

Accident numbers are considered as the actual number of causes for each classification and the amount, in dollars, compensated for each classification of injury.

Accidents and associated injuries are analyzed as to cause, part of the body injured age of victim, nature of the injury, agency involved and number of days lost.

Pennsylvania Department of Labor and Industry, Bureau of Research and Statistics, "Injury Rates, Industrial Accident Survey, Pennsylvania 1968", Harrisburg, Penn., August 1969.

This survey was based on returns to questionnaires sent to non-farm wage and salary establishments employing 5 or more workers. Usable data was received from 26,992 units employing a total of 1,865,018 workers. The 7,910 reporting manufacturing units employed 1,018,619 workers.

Injury frequency rates and severity rates are given for each of the industries classified as to product. Rates are given for 1968 and 1967 and the percent change from 1967.

Pennsylvania Department of Labor and Industry, Bureau of Research and Statistics, "Work Injuries in Pennsylvania 1968", Harrisburg, Penn., August 1969.

During 1968 there were 96,512 on-the-job injuries reported to the Bureau of Workmen's Compensation.

Accidents and associated injuries are analyzed as to cause, part of the body injured, sex of the victim, hours worked, industry engaged in, occupation, and unsafe mechanical or physical condition apparent at time of mishap.

SOUTH CAROLINA -

South Carolina Industrial Commission, "34th Annual Report of the Industrial Commission to the General Assembly, July 1, 1968 - June 30, 1969", July 1969, pp. 58.

The 74,450 injury cases in fiscal 1968-1969, handled by the Industrial Commission are analyzed in this publication. These are noted as to industry group, type of disability, cost, cause of injury, county in which they occurred, location of injury and nature of the injury.

An analysis of the 133 fatalities that occurred during this time period is also included.

WASHINGTON -

State of Washington, "21st Report of the Department of Labor and Industries, Fiscal Year 1967 and 1968".

The Industrial Insurance Division administers the Workmen's Compensation Act and is responsible not only for disbursing compensatory funds, but in the gathering of accident data.

The Safety Division's primary responsibilities include accident prevention and wholesome industrial environmental control.

Included in this report are accident statistics gathered under the Workmen's Compensation Act and include industrial fatalities as well as non-fatal injuries.

These are analyzed as to frequency and number of days lost as well as by cause of injury.

Part 4

HUMAN VARIABLES IN ACCIDENTS

An unlimited number of hypotheses have been advanced as the ultimate cause of human induced accidents. However, none of these has ever been irrevocably proven as the one significant factor in accidents. Perhaps, as in most human behavior, there is no single overriding reason, but instead, a multitude of causes operating at any given time.

As is noted in this section, innumerable variables can effect a person causing him to become unaware, unconcerned or careless about his surroundings, his work, and his safety. Factors present in his job, his environment, his home and in himself could be the potential trigger for an accident.

The Relation to Age & Experience

In determining the relation of age and experience to the accident rate, it is difficult to separate the two and determine which is the determining factor: age or experience or a combination. Most studies (although not all) have concluded that the older, more experienced worker has fewer accidents, although he has more disability days per accident.

In these studies, distinctions have not been made as to actual functions of the young and old workers, only to occupation title. Whether the older worker is actually performing the same tasks as the younger is certainly a determining factor in comparing their accident rates.

Chambers, E. G., "Psychological Tests for Accident Proneness and Industrial Proficiency", Medical Research Council, London, England, Memo 31, 1955.

see annotation: Physical Factors and Mental Abilities as Related to Accidents

Funk, G., "The Relationships Between Age, the Frequency of Industrial Accidents and Their Sequels", Zeit Schrift fur Praventiv Medizin, Vol. 12, No. 3, pg. 160-178, 1967. Abstract taken from Excerpta Medica, pg. 146, Feb. 1968.

In the production sectors of an agricultural machinery factory 1,485 work accidents were recorded among the male employees from 1961-1963. The accidents were related to the process of production and caused absence from work of 4 days and more. The following statistical deductions may be made: The frequency of accidents varies with age: it is maximal among young persons aged 22-24 yr., and becomes less after 50 yr. of age. The accidents (save those which happen to apprentices) due to inattention, the nonobservance of the protection measures and lack of qualifications are most frequent in the group of young persons working full time in production. As age increases such accidents fall off gradually and other factors become operative. The frequency of the accidents depends on the number of years of service (the period of adaptation may last as long as 5 yr.) and, in consequence, on the age of the employees. The duration of inability to work increases with age on account of the nature of the injuries which changes with age, and also because of prolonged convalescence. The age structure of all employees has been compared in this study with that of the accident victims; this is the only method which makes it possible to arrive at valid conclusions as to the frequency of accidents.

Godec, "Personality Characteristics of the Accident Repeater", Safety Maintenance, v. 134, 3:13-16, Sept. 1967.

The tendency to have accidents is measurable and predictable. A test, the AR-11 was developed to predict and screen the individual who is an accident repeater. This test covers the personality of the individual, since it was found that the accident repeater has a particular character syndrome. The responses an individual makes to the full test are converted into a score called the Safety Index.

In determining the reliability of this test, it was found that as the men became accustomed to the requirements of their various jobs, over a given length of time, accident rates decreased. The men who had by far the most accidents left the job before working more than six months. The 79 percent of this group who worked no more than 4 months accounted for half the time-lost accidents.

Griew, A., "A Study of Accidents in Relation to Occupation and Age", Ergonomics, 2 (1), 17-23, Nov. 1958.

This study, conducted at a large factory producing aero-engines, investigated the accident rate as related to age and occupation for the various crafts, from Jan. 1953 through Dec. 1956.

An accident rate for each job and for each of six age groups within jobs was calculated. The expected numbers of accidents occurring in the six age groups of the job during the course of the study was weighted according to the overall accident rate of the job.

The study concluded that accident rates in some jobs do appear to increase with age to a greater extent than in others. The jobs in which high accident rates occur in the upper age groups seem, on the whole, to be those in which there is a preponderance of younger workers.

Kossoris, M. D., "Absenteeism and Injury Experience of Older Workers", Monthly Labor Review, 67:16-19, July 1948.

A study of 17,817 workers distributed as to age and sex was conducted to determine the absentee and accident rates relative to these age groups.

The absenteeism rate, i.e., the number of days lost per 100 workdays during which the workers were scheduled to work, decreased consistently as age increased.

The frequency rate of disabling injuries for workers between the ages of 55 to 69 years was about the same as that for the 45 to 49 year group. This rate, in turn was only fractionally higher than that for the 25 to 34 year group. The highest accident rates occurred in the groups from 35 to 44 years.

Larke, W. M., "Leadership for Accident Prevention", U. S. Department of Labor, Bureau of Labor Standards, Bulletin No. 263, June 1964.

Employees with less than 2 years experience are more liable to have injury producing accidents than an employee with more than 2 years service at the same occupation.

Newcomers (less than 2 years experience) have a lower absentee record, for ailment induced absences. After 2 years experience, the employee conforms to the work patterns and absentee policy (the "understood" policy) within the company. Therefore he lowers his accident rate and increases his absences.

Van Zelst, R. H., "The Effect of Age and Experience Upon Accident Rate", Journal of Applied Psychology, 38:313, 1954.

The effect of job experience upon the accident rate of the workers is considerable for the first five months of employment, but seems of little significance beyond this.

This longitudinal study of 1,217 workers at a copper plant compared a young group of workers with an older group, with roughly the same job experience, 3 years. The younger group had an accident rate above the department level, whereas the older group was below that level. A third group, mean age 2 years younger than the old group, of inexperienced workers was also studied. These inexperienced workers showed an early sharp decline in the frequency rate and than leveled off at the older groups rate.

Formal training in the correct job procedure and safety methods produced a lower initial accident frequency rate.

Human Reliability

Consideration of the human variable in accidents includes the analysis of human reliability--the human error rate. The human element accounts for a majority of errors and failures consequently these entail accidents. Efforts to account for that element, the human reliability, and to improve upon it could reduce errors and accidents.

Askren, W. B. (ed), "Symposium on Reliability of Human Performance In Work", (conducted as part of the 1966 Annual Convention of the American Psychological Association.), pg. 45, May 1967.

This report is a compilation of the papers presented during the symposium, "The Reliability of Human Performance in Work" at the 1966 Annual Convention of the American Psychological Association. Dr. Altman's paper is concerned with the classification and combination of human error data in psychologically meaningful ways. He examines alternative ways of classifying human error to facilitate integration of error data for some practical limitations in using the simple multiplicative model with a molecular definition of behavioral elements to estimate task reliability in man-machine systems. He describes advantages of estimating conditional probabilities of larger (molar) units of behavior when employing the probability tree technique in reliability analysis. Dr. Meister's paper addresses the importance of production worker error to system reliability, together with characteristics that differentiate production error from operating error. Factors that predispose to worker error are analyzed in the context of the production process as a man-machine system.

Christopher, J. W., "Man as a Part of the Design Environment", Proceedings of the 1970 Annual Symposium on Reliability, Feb. 3,4,5, 1970.

Workmen should be included as one of the environmental variables that must be considered in design. The design is not complete unless the designer assumes responsibility for the survival of his product as it interfaces with workmen during fabrication, assembly, test and use.

Problems are classified as to human initiated and insufficient information to classify. Therefore man should be reinvolved in every problem solution: humanize reporting, analysis and corrective actions. Human factors research should be used as soon as possible to utilize a problem orientation rather than a failure orientation.

Davis, Ben P., and Cordoni, Carl N., "People Subsystem Measurement for Total Reliability", Proceedings of the 1970 Annual Symposium on Reliability, Feb. 3,4,5, 1970.

Introduction of frame of reference parameters that represent "best fit" conditions by which Personnel Subsystem malfunctions can be controlled entails three operational system components: hardware, personnel, and management procedure concept.

To approach an interrelationship of the three, a conceptualized Intersection Measurement Tool is used consisting of 3 subsets each containing 2 parts: one associated with one of the above basic components, and a corresponding component related to the other basic component.

A computer model expedites the analysis of Personnel Subsystem Malfunction data structured to a fixed work interval. The model controls the design, production and test of a personnel system.

Swain, Alan D., "Human Element in System Development", Proceedings of the 1970 Annua Symposium on Reliability, Feb. 3 4,5, 1970.

Consideration of the human element includes the application of human factors technology to increase human reliability in a system. Where possible, human reliability analyses should be performed to obtain estimates of human error rates for inclusion in system reliability studies and to evaluate recommended design changes.

The human element often accounts for a majority of system failures. Therefore, any efforts to improve consideration of the human element should improve system effectiveness.

The article introduces a 10 step program to consider man in the systems through various stages of systems planning, design, manning and evaluation.

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Job Factors Relating to Accidents

Not only should the individual and the machinery be considered in reducing accidents, but also important is the occupation, tasks, methods, and the company.

In making a company safer, human engineering and the introduction of protective clothing are necessary, as well as an investigation of the work environment as to noise, psychological climate, and physical comforts.

To minimize accidents in a particular occupation, that occupation should be noted as to its indigenous hazards, the amount and effect of safety instruction and the sustaining incorrect methods.

Bird, Frank E., Jr., "Damage Control", National Safety News, pg. 35-7, April 1962.

A large portion of accidents result from repetitive methods or actions that, if uncorrected, continue to cause accident loss in the form of property loss or personnel.

deStwolinski, L. W., "Safety Environment of the Construction Industry. A Survey", Stanford University, Dept. of Civil Engineering, Stanford, California, pg. 111, Sept. 1969.

The purpose of circulating a questionnaire to members of Operating Engineers Local Union No. 2 was to obtain employees viewpoints on safety programs and attitudes in order to determine what correlations if any existed between these factors and injuries.

Important findings of this survey are:

Employees do stay with or return to individual employers for enough time to justify substantial expenditures for their training both in skills and in safety.

Employees do prefer specific companies and for specific reasons. Factors considered to be most important to non-supervisory personnel include, in order of significance:

1. Pleasant conditions on the job and with supervisors.
2. Safe working conditions in actual practice and in the attitudes of supervisors.
3. Security measured by length of employment.
4. Greater monetary reward in overtime.

There is a direct relationship between minor and lost time accidents and the presence or absence of effective safety instruction at the time of initial employment. Those receiving instructions to their satisfaction have significantly better records than those who were not given instruction, or who did not understand or were not given effective instructions.

Except for the requirement for hard hats (60%) little else in the line of safety equipment is required by contractors.

More than 40 percent of the workers feel, either strongly or somewhat strongly, that risk taking and minor injuries are characteristics of the work environment. A significantly higher percentage of those having lost time or minor accidents feel that risk taking and minor accidents are a part of the job than those who have not had a lost time accident in the last five years or a minor accident in the last year.

Discussed also are the accident/non-accident characteristics of workers; desire of change of job and reason; correlation between lost time accidents, minor accidents, near misses and traffic accidents of the workers.

Fugal, G. R., "Reducing Industrial Accidents", Harvard Business Review, pg. 82-90, July 1951.

Most industrial accidents are due to poor worker attitudes and lack of knowledge or skill about the job. Both of these causes may be influenced quite substantially by individualized safety education, which is quite effective not only in reorienting the individual's thinking about his job but in inducing better work habits.

The accident problem is not unlike that of any other industrial problem where employee cooperation is a critical factor. Relatively unfavorable accident frequency rates in given plants cannot withstand the strong light of managerial interest, praise, and criticism.

Girard, G., "Environmental Motivations and Conditions Affecting the Employment of Individual Protective Equipment", Securitas. Vol. 53, No. 5-6, pg. 173-195., 1968. Abstract taken from Psychological Abstracts, Vol. 44, No.2, pg. 295, Feb. 1970.

This article relates the conclusions of a psychological study concerning individual protective equipment used in the steel industry. The fundamental assumption is that the worker primarily aims at complying with the needs of his employer, and that work safety remains a noble, but relatively ineffective end until immediate danger arises. The behavior patterns suggested by experience are all operative, either of avoidance or of escape, capable of being immediately put into practice. The use of protective equipment, is a preventive behavior. It is concluded that the experimental determination of the effectiveness of the protective equipment cannot always be interpreted in an unequivocal manner and is effected by means of preexisting attitude.

Groner, Pat N., "The Private Hospital's Interest in Employee Health and Safety", U. S. Department of Labor, Bureau of Labor Standards, Bulletin No. 263, June 1964.

Accidents occur even though the hazard is known to the employees, protection is provided by safety devices or a particular procedural method. These accidents occur when the people exposed to the hazard are not educated fully to the potential danger and are thus not moved to use the safer method.

Keenan, Vernon, Kerr, Willard, Ph.D., and Sherman, William, "Psychological Climate and Accidents in an Automotive Plant", Accident Research Methods and Approaches, Harper and Row, 1964.

In the belief that certain factors of psychological climate and physical environment may be of great importance in the causation of accidents in heavy industry, the authors formulated a series of hypotheses and investigated 7,103 individuals' lost time accident record at a tractor factory for the 1944-48 five year

period.

Results suggested fewer accidents in departments with above average variation in production pressure; it is possible that variation in production pressure tends to reduce accidents by reducing monotony and encouraging alertness. An accumulation of physical frustration tensions leads easily to "distractive" behavior which often results simultaneously in reduced quality of work and accident.

High accident departments are characterized by less physical comfort and a demand for greater manual effort; also these are of lower average prestige value.

Larke, W.M., "Leadership for Accident Prevention", U.S. Dept. of Labor, Bureau of Labor Standards, Bulletin No. 263, June 1964.

see annotation: The Relation to Age and Experience

Maugeri, S., and Odescalchi, C. P., "Occupational Noise: Present-Day Problems, Pathology, and Preventive Measures", Securitas, Vol. 53, No. 5-6, pg. 33-169. Abstract taken from Psychological Abstracts, Vol. 44, No. 2, pg. 296, Feb. 1970.

This article describes the characteristics of noise (intensity frequency, duration, timbre, etc.) and draws a distinction between occupational and nonoccupational noise. The effect of the noise is felt across the channels of the sympathetic system and, centrally, on the diencephalic centers (reticular substance). Occupational noise harms the hearing organs of the worker in a characteristic and constant manner, and frequently is the cause of accidents as a result of interfering with verbal communications. It affects the performance of man-machine systems and disturbs the community at large. The prevention of the damage caused by noise must begin by acting on the source of the noise itself and on the work environment. A criterion for evaluating the risk, based on daily exposure to noise for a period of 290 working days is proposed. A review of technical and medical prevention, and occupational audiometry both at the time of starting work and periodically repeated is presented.

Personnel Magazine, "Industrial Accidents--Facts Behind the Figures", Dec. 1965.

The present basis of accident reporting results in misleading statistics and does little to improve accident prevention. There is no relationship between injury severity and the amount of time lost.

The other main factor is the nature of the person's occupation. In general, the more complex the job, the higher the accident rate. Despite what may be said about the danger of monotonous and repetitive work, and the safety of the skilled worker, it is

the latter, with his greater opportunity to depart from the safe working method, who has the higher rate. Major injuries also end to related to occupation, e.g. finger amputations to porwer press setting.

Sanders, Eric P., "Relation Between Accident Incidence and Type and Level of Job", Psychological Reports, 14:670, 1964.

From 597 employees in a hospital, incidence of accidents was recorded. An accident was defined as an event which caused injury to some part of the body and required that the employee report to a clinic.

The results indicated that hazard exposure varies with job levels of hospital personnel, there being a greater accident rate for jobs in lower levels than for jobs in higher levels, and within a job level, there are no significant differences in accident rate. It therefore appears, that the concept of job level is of value in accounting for some of the variation in accidents between various occupations.

Sell, R. G., "The Psychology of Safety", Paper presented at the Conference of the Institution of Industrial Safety Officers.

Young, D. L., "Credit Difficulties and Accidents", Personnel Journal, pg. 168, October 1959

An 18 month study was conducted on employees of a steel warehouse. It was found that those with credit difficulties (persistent difficulties) had 51 percent more accidents in the 18 month period.

Also found was the more highly educated manual employees had significantly more frequent accidents than those with less education. It appears that overeducation for a job may result in boredom and apathy or pressure (social) that tends to increase liability to accidents. In addition, low mobility and low promotion probability is associated with a high accident frequency rate.

Physical Factors and Mental Abilities as Related to Accidents

One cannot do his job correctly or reach maximum production if he has a physical or mental defect that impairs his abilities. Subsequently, one cannot be adequate in his job if he doesn't understand what is to be done or lacks the judgement necessary to do it.

This can also be a requisite factor in accidents. If one has a physical defect that impairs his response, poor visual skills that make perception of a hazard difficult, or is physically ill or mentally tired making him lethargic, his judgment and subsequent actions may not protect him from an impending accident.

If he does not know safety techniques or doesn't realize their value, his judgement and abilities in the use of these techniques in a potentially hazardous situation will most likely be poor and lead him to an avoidable accident.

Chambers, E. G., "Psychological Tests for Accident Proneness and Industrial Proficiency", Medical Research Council, London, England, Memo 31, 1955.

Various tests were given an accident group and an accident-free group to determine if there is any relationship in the tested areas and the prediction of accident victims. A relationship between the kinesthetic tests and accidents for skilled workers and transport drivers was found; those with a higher accident rate generally had a lower score on the kinesthetic test.

In this study, it was found that those with a higher accident rate had higher absenteeism due to sickness alone.

Youth and inexperience were also related to higher accident frequency, however it was not determined how much each contributed since these were usually correlated together and are generally inseparable.

Crawford, P. L., and Ashford, W. F., "The Psychology of Accident Prevention", Psychology of Management Series, No. 1.

This monograph presents a general review of human causes of accidents and their prevention in an industrial environment. Accident factors are classified as physical, psychological and social and the orientation toward the control of these factors are through the pre-employment and post-employment practices.

Three general reasons for unsafe behavior are summarized as follows:

1. An individual may not see, hear, or otherwise perceive the work environment which allows him to perform a particular act or to make a proper decision safely. Physical defects or other defectve sensory receptors may contribute to one's failure to recognize proper environmental stimuli.

2. An individual may perceive the environmental hazards but he misinterprets them in terms of safety. Lack of safety training to identify hazards, poor work habits, wrong attitudes toward safety, or low intelligence may interfere with an employee's interpretation of environmental conditions.

3. Other internal or external stimuli may reduce an individual's general awareness of immediate environment; thus, he fails to relate his behavior to job hazards. Interest in other things, poor safety attitudes, or any condition which diverts one's attention will tend to reduce one's awareness of his immediate environment. Consequently, an individual may fail to anticipate the results of his behavior in terms of safety.

Therefore, appropriate methods for reducing employee accidents include: 1. proper selection and placement in reference to the individual's abilities, aptitudes, and interests based on job requirements; 2. creating and maintaining safe working conditions by improving training, making supervision more effective; and 3. providing a receptive ear to employee's personal problems.

Davis, D. R., "Human Errors and Transport Accidents", Ergonomics, 2 (1), 24-33, Nov. 1958.

This paper is concerned with three psychological processes and their effects on transportation accidents particularly air and rail transportation. The three processes are: false hypothesis, responding to a situation as one conceives it to be and not as it actually is; pre-occupation, perceptual narrowing and concentration toward certain controls and the neglect of others; and emergency mechanisms, the increased drive and sensitivity which can be advantageous and at times, disadvantageous.

Examples of air and rail accidents, where one of these processes was likely to be at fault, are given.

Haddon, Suchman, and Klein, "Menstruation and Accidents", Accident Research Methods an Approaches, Harper and Row, 1964, pg. 203.

In this survey 52 percent of a total of 84 regularly menstruating women were involved in an accident during menstruation or the four days before menstruation. The significance of menstruation as a factor affecting accident-proneness persisted among home, road, and factory accidents, while women were performing routine actions, and among the active and passive participants of an accident. It is suggested that the increased lethargy of menstruation and the premenstrum is responsible for both a lowered judgment and slow reaction time.

Keenan, Vernon, Kerr, Willard, Ph.D., and Sherman, William, "Psychological Climate and Accidents in an Automotive Plant", from: Haddon, Suchman & Klein, Accident Research Methods and Approaches, Harper and Row, 1964.

See annotation: Job Factors Relating to Accidents

Kolb, D. W., "Human Factors Implications in Product Safety", Purdue University, Lafayette, Indiana, pg. 64, June 1968.

The human being is frequently studied as the cause or source of accidents through his negligence and misuse of products. Products are also analyzed as contributors to accidents, normally with mechanical, electrical, and materials standards serving as criteria. These approaches to product safety are man or machine. They overlook the interaction of men and machines, and how the machine may be contributing to injuries through inadequate consideration of human abilities to use it.

The man and machine orientation in injury reduction constitutes the human factors realm of product safety. Several accident studies, most notably the one of Fitts and Jones concerning

pilot errors in operating aircraft controls, have shown the human operator of equipment to be unjustly judged negligent.

Naus, A., "Work Injuries and Smoking", Industrial Medicine and Surgery, 35:880-1, Oct. 1966.

A study of smoking as one of the factors that influence the incidence of work accidents was carried out. The results show a prevalence of smokers in the group of injured workers. The interpretation of the facts indicate that it is possible to suppose that the habit of smoking causes injuries due to the loss of attention and to the occupation of hands or to the irritation of eyes, to the cough, etc..

Tiffin, J., Parker, B. T., and Habersat, R. S., "Visual Performance and Accident Frequency", Journal of Applied Psychology, XXXIII, 499-502, October 1949.

Two groups, one an accident group and the other an injury-free group, were matched and studied as to the difference in their visual ability. The injury-free group of workers were found to have superior visual skills.

Psychological Causes and Personality Variables

The majority of accidents at any given company involve only a minority of the personnel; many times, only a few people are responsible. This individual has been called accident prone or an accident repeater. His personality has been studied, tests have been devised to select for these individuals and clinical research has sought to rehabilitate him.

Many researchers feel this trait is permanent in any given individual, while others feel the propensity for accidents is brought on by incidents in the victim's life and is only as temporary as the problems initiating it.

However diverse the research some results are common to many. The person involved in accidents is thought to have a poor adjustment to his life situation and generally does not stay at one company a long time or he outlives this accident period and becomes a permanent worker.

Adler, A., "The Psychology of Repeated Accidents in Industry", American Journal of Psychiatry, v. 98, pg.99, 1941-42.

A clinical study of 130 workers who had repeated accidents revealed their revengeful attitude toward parents and educators; they blamed others for their unhappy life and felt that they were just unlucky.

These accident repeaters were compared to a control group of 20 who had had no accidents. Their dreams, childhood recollections, and emotional reactions were studied, and various psychometric tests were given them including manual ability, concentration and reaction time. Neither the psychometic nor constitutional examination showed any difference between the control and the "accident-prone" workers.

Dunbar, F., "Medical Aspects of Accidents and Mistakes in the Industrial Army and in the Armed Forces", War Medicine, 4:161, 1945.

Persons who have had one major accident are those who are most likely to have other major accidents, unless it can be definitely ascertained that this accident belongs to the 10 to 20 percent in which the personality factor has not entered. Also a person who has a history of many minor accidents is the person who is most likely to have a major accident. This person is accident-prone.

The personality of the accident-prone individual is related. These people typically do not finish the educational courses which they undertake, have an unstable work record, experience many changes in their jobs coupled with ups and downs in their incomes, are spontaneous and casual in their social relations and have superficially good sexual adjustment but are irresponsible toward their sexual partners and family.

Freeman, F., Goshen, C. E., and King, B. B., "The Role of Human Factors in Accident Prevention", U. S. Dept. of Health, Education, and Welfare, Bureau of State Services, 1 August 1960, pg. 105.

The objective of this study is to determine the contribution that a more thorough understanding of human factors can make toward enabling man to live safely in the presence of danger.

An extensive review and analysis of research methods and findings on the role of human factors in accident causation and prevention was undertaken. The following human factors are discussed as they relate to safety: physical and behavioral development, aggression, emotions, physical fitness, human stress tolerance, selection techniques, psychological and sociological maturation, self identification with safety messages, communications, disease, physical impairment, supervision and enforcement, and accident investigation.

Godec, M., "Personality Characteristics of the Accident Repeater", Safety Maintenance, v. 134, 3:13-16, Sept. 1967.

See annotation, Age and Experience.

Hayakawa, S. I. Dr., "Making Safety Meaningful: Conditions of Success in Communications", Proceedings of the Presidents' Conference on Occupational Safety, U. S. Department of Labor, Bureau of Labor Standards, Bulletin No. 263, June 1964.

The situation is named and the name is then "acted-out" or "lived up to" in another. The way we formulate our experience and perceptions governs our behavior toward them and linguistic formulations are frequently inadequate in the case of safety information and procedures.

Hempel, E., Kneist, W., and Petermann, A., "A Longitudinal Study of the Causes of Accidents in a Large Factory", Dtsch. Gesundh.-Wes., Vol. 22, No. 20, pg. 948-952, 1967, Abstract taken from Excerpta Medica, Vol. 14, No. 8, pg. 763, Aug. 1968.

The causes of 5,000 accidents in a large Erfurt factory for a period of 13 years were analyzed. After having eliminated time and local random findings, it was possible to ascertain that on the average no essential lowering of the accident rate had been reached in this factory. In departments of central importance the accident rate could, however, be temporarily lowered by enlightening the staff on the causes of accidents in detail, such as in the transportation department. Those accidents which are due to "human errors and faults" have still to be cleared up, opening a broad field of work for labor physiologists, factory psychologists and factory sociologists. Their results of research would help to lower the rate of accidents at the working place to an optimal minimum. In view of the little progress achieved so far in lowering this accident rate such help is required all the more urgently.

Hirschfeld, M., "The Accident Process: I. Etiological Consideration of Industrial Injuries", Journal of American Medical Association, 186:193-9, Oct. 19, 1963.

The accident syndrome develops because of socioeconomic, emotional and sometime legal reasons. The actual physical injury is a result of the psychological process; the victim becomes depressed before the accident, causing an increasing sense that he cannot take care of himself. Therefore he becomes incautious and lack-adaisical, and neglects to pay attention, actually seeking destruction.

Accidents have been found to be caused by multiple infractions of safety rules, usually things a novice would never do. The accident process begins as a result of the victim's conflict and anxiety. The worker finds a self-destructive injury producing act that will cause his "death" as a worker.

Newbold, E. M., "A Contribution to the Study of the Human Factor in the Causation of Accidents", Medical Research Council, Industrial Fatigue Board Report, No. 34, 1926.

The author's intent was to examine "the extent of existence of individual workers having a distinct tendency to incur accidents", and "the statistical correlation of accident incidence with age, sex, experience, health, and output." A study was conducted of 22 factories and 16,188 accidents.

The study revealed that the average number of accidents is much influenced by a comparatively small number of workers, and that the distributions among the workers are far from chance ones. There is a tendency for the number of accidents to decrease to some extent with age and apparently also with length of service (but when allowance is made for age, there is no independent association between experience and accidents). The consistence of individual tendency to accident is shown by the association found between: accidents in two different periods; accidents of one type and of another type; and accidents in the factory and accidents at home.

Sachs, M., "Psychosomatic Aspects of Accidents", Industrial Medicine and Surgery, 31:525-32, Dec. 1962.

The accident prone person likes excitement and adventure and does not like to plan for the future--he is impetuous.

These people have a common origin, rebellion against restrictions by authority and all forms of external coercion. However, he feels guilty about his rebellion.

The unconscious accident expresses his resentment but also offers him an outlet to atone for his feelings via the injury to himself.

Schulzinger, Morris S., M.D., The Accident Syndrome, Charles C. Thomas, Springfield, Illinois, 1956, pg. 234.

The accident syndrome, recurring manifestations of which only the details vary from incident to incident, is mainly dependent on the contribution of the victim. Therefore, accident control lies in an understanding of the life factors of the person rather than an approach to mechanical or environmental hazards. Furthermore, the author views accidents as a disease syndrome, therefore the clinical (medical) approach is the only way to deal with tho irresponsible and maladjusted individual, his family, environment and his behavior--the factors contributing to accident causation.

These conclusions are based on the medical records of 35,000 consecutive accidental injuries, industrial and nonindustrial, covering the period 1930 to 1948. However, these records are limited to those people who felt the need to seek medical atten-

tion for their injuries.

These and other conclusions of accident causation, such as accident causation, such as accident proneness, susceptibility to accidents, age and time distributions of victims and accidents, as well as the personality and background of the victim are supported by various graphs and tables based on the medical and psychiatric data of the 35,000 cases collected by the author.

Sell, R. G., "The Psychology of Safety", 196_ pg. 13. Paper presented at the _conference of the Institution of Industrial Safety Officers_.

The ways in which psychology can contribute to the field of safety are described. The accident proneness approach is adjudged inferior to the method of considering people in relation to the job which they have to do. Difference of age, personality, and skill are shown to be worth consideration, and the factors involved in influencing behavior are analyzed. Ergonomics, the consideration of human capacities and limitations, is brought out as the most important contribution of psychology to the field of safety. Under this head the importance of expectancy, short term memory, perceptual problems, and risk taking is shown. In conclusion a tripartite approach to the problem of safety is sketched out.

Weil, R. J. and Sewell, M. A., "Some Psychiatric Aspects of Industrial Accidents", _Industrial Medicine and Surgery_, 36:181-4, Mar. 1967.

From a personality study of 51 accident victims, the main accident determinant was found to reside within the individual. The study revealed the potential accident victim has the following characteristics: basically passive and dependent, middle-aged reaching the end of this working career, an apparent lack of interest or concern for his enviornment, sudden changes in attitude and/or behavior.

Whitlock, John B., Jr. and Crannell, Clarke W., "An Analysis of Certain Factors in Serious Accidents in a Large Steel Plant", _Journal of Applied Psychology_, 1949, v. 33, 494-498.

From the Bernreuter Personality Scale, three elements differentiated the accident cases, they appeared less neurotic, had a tendency toward high dominance scores and low extroversion scores.

Further personal data was gathered on a control group and three accident groups, distinguished by the amount of responsibility given them for their accident:total responsibility, joint responsibility, and accident due to lack of action by someone else. Discrepancy was found between the accident groups and the control group on a number of areas of this data that included age of individual, number of dependents, weekly wage, length of service with the company and education.

Wong, W. A., MD, and Hobbs, G. E., MD, "Personal Factors in Industrial Accidents--A Study of Accident Proneness in an Industrial Group", Industrial Medicine, 1949, 18 291-294.

This article discusses the Accident Prone Worker, that small number of workers who have many more accidents than can be explained on the basis of pure chance. This accident prone group showed more frequent work errors, poorest attendance; they were vocational misfits given to inattention, worry and unwillingness to take supervision.

In this study, the high and low accident individuals differed in their social adjustment; the high accident group had a conflict with authority in childhood and adulthood, an aggressiveness that led to difficulties in their personal life.

The accident prone worker can be identified by an analysis of the frequency of superficial injuries since the tendency to accidents is a stable characteristic. Only the extent of the injury is determined almost entirely by chance owing to circumstances present at the time of the mishap.

Stress, a Contributing Factor in Accidents

It is generally agreed that stress exists in the work situation; the presence of stress is not conducive to a productive or safe environment.

Stress leads to errors, fatigue, lack of good judgement, mental preoccupation and the conscious or unconscious wish to escape the situation.

Stress occurring in work situation creates absences and accidents as a means of escape. Stress occurring in the general life situation carries into the work situation where the means of escape is available, the accident.

Release of tension and stress is desirable, however the outlet for this does not now exist in the industrial environment.

Brody, Leon, Dr., "Human Aspects of the Accident Barrier", Proceedings of the President's Conference on Occupational Safety, *U. S. Dept. of Labor, Bureau of Labor Standards*, Bulletin No. 263, June, 1964.

The accident potential of an individual increases when he is under stress or uneducated in safety matters either through his own fault or that of the company's.

When under stress, the individual is more inclined to do things against his better judgement or not bother to judge. If he is not knowledgeable of safety methods or devices, his judgement is uneducated and thus subject to greater error. Each of these three types of judgements will potentially lead the individual to an accident.

Castle, P. F. C., "Accidents, Absence, and Withdrawal from the Work Situation", *Human Relations*, 9, No. 2:223-33, 1956.

Two hypothesis are postulated on the relation of absences to the frequency of accidents. One, the Withdrawal Hypothesis, states that accidents are a method of withdrawal from the work situation as are absences. The frequency of accident absences was found to correlate with the frequency of other absences.

The second hypothesis, the Sanctioning Hypothesis assumes that accident absences are the most sanctioned type (the most legitimate reason), and, based on the first hypothesis, these would correlate with the least sanctioned type of absence (absent without a legitimate reason) if accidents are used as a means of withdrawal from the work situation. This correlation was found to exist.

This article treats the question of accidents being used as "legitimate social behavior" in the lack of acceptance of resonsibility on the part of the individual.

Craig, E. A., "Situational Stress and Safety", *Personnel Journal*, May 1966, pg. 269-72.

Sensory overloading causes stress; this overloading is many times caused by distraction from work.

Under stress the behavior is variable, there is a loss of precise control of movement. In addition, there is reduction in the ability to predict future outcomes and the behavior is then oriented to the immediate goal, the preoccupation with one's emotions.

In a stressful situation, every part of the individual is ready for action, however there is no outlet available. To remedy this, the author suggests having an object to hit so that the potential energy is translated into action, thereby alleviating the stress.

Gass, M., "A Psychologist Looks at Accidents", Occupational Health Nurse, 17:9-11, Oct. 1969.

Many major accident victims have in common a sequence of events leading to the disabling accident. Many accident victims sometimes recall a premonition of something to happen. At the first outward sign of this accident sequence, tension is triggered and minor mishaps and accidents occur.
The author sees accidents as a partial solution from life problems. Once the accident occurs, the victims focus is shifted from the intolerable life situation to the pain and discomfort of the accident.

Hill, J. M. M. and Trist, E. L., "Changes in Accidents and Other Absences with Length of Service in an Iron and Steel Works", Human Relations, 8, 2:121-52, 1955.

Absences are a "stayer" phenomenon; one of their uses is to provide a means of temporary withdrawal from the stress of continuing in (rather than breaking from) a work relationship.

Accidents are used in part as a means of withdrawal from the work situation. Accidents occur more to the deviating minority rather than the normal "stayer" majority who conform to the social norms of absence behavior.

"Stayers" learned the prevailing absence culture and operate in it more freely. As he becomes to identify with the company leaving is less available to him as means of alleviating the stress from the relationship.

Hill, J. M. M. and Trist, E. L., "A Consideration of Industrial Accidents as a Means of Withdrawal from the Work Situation", Human Relations, VI, 4:357, 1953.

The level of accidents at any given time is dependent on the opportunities for accidents (risks and hazards of the job) and the propensity of the individual to take these opportunities.

Accidents may be frequently (but not necessarily) related to personal characteristics of those sustaining them, and as a result accidents may be consciously or unconsciously motivated by the individual concerned. This motivation is to injury and/or absence from work as a result of the accident.

Absences, in general, are a result of interaction of the individual with the work situation plus the amount of interference from events in the rest of his life.

In this study, the departments where the most accidents occurred (the most hazardous areas), the most absences also occurred. This could be attributed to the different reactions to the same work situation, since those with accidents were absent more than those without accidents.

Thus, the accident and absence phenomenon reflects the quality of the relationship of the person in the employing institution. This is affected by the extent the individual perceives the firm as a good employing authority, to whom he acts in a responsible way.

Muechner, Hans and Ungeheuer, Hans, "Meteorological Influence on Reaction Time, Flicker Fusion Frequency, Job Accidents, and Use of Medical Treatment", Perceptual and Motor Skills, 12:163-8, 1961.

Characteristic changes of cloudiness, solar radiation, temperature and relative humidity, atmospheric pressure, wind velocity and zone level as a function of weather phase were studied in connection with their effect on reaction time, job accidents, the use of medical treatment, and the flicker fusion frequency.

It was found that advective disturbances result in psychological and behavioral effects which may be "bionegative" as compared with the phase of normal radiation and rhytnm.

Excessive aplitudes or levelling of the diurnal variation, as well as aperiodical processes due to influx from outside, must be regarded as stresses which cannot be fully compensated by the organism and thus lead to various types of decrement in behavior and sensory functions.

Pearson, David W., Ph.D., and Thackray, Richard I., Ph.D., "Consistency of Performance Change and Autonomic Response as a Function of Expressed Attitude Toward a Specific Stress Situation", Dept. of Transportation, Federal Aviation Administration, Office of Aviation Medicine, AM69-7, April 1969.

An individuals cognitive appraisal (expressed attitude) of a threatening object or situation may be subsequently manifested in a consistent manner irrespective of the task employed. However, this may be only within certain limits insofar as consistency across tasks is concerned.

Different degrees of threat may be elicited by different stressors. Significant performance or physiological changes would occur whenever shock or threat of shock (by the stressor) is introduced.

Rigby, Lynn V. and Edelman, David A., "A Predictive Scale of Aircraft Emergencies", Human Factors, 10 (5), 475-482, 1968.

This study provides a more substantive basis than was previously available for quantifying human performance in the face of emergency.

It is commonly assumed than under high stress the error rate for pilot tasks will be 10 to 20 percent and the error rate for inflight tasks by other crewmen will be 5 to 15 percent, assuming a rate of 0.01 task unreliability under benign operating condition with reasonably well human engineered equipment.

The mean human error rates provide estimates of the probability that aircrew tasks will be malperformed in the face of given emergencies. Inasmuch as there were practically no differences between pilot and nonpilot pair comparisons, the same error rates should apply to both types, and these stress levels and error rates should apply to non-aircraft situations.

Rusk, Howard A., Dr., "Making Safety Motivate: The Personal Importance of Accident Avoidance", Proceedings of the President's Conference on Occupational Safety", U. S. Dept. of Labor, Bureau of Labor Standards, Bulletin No. 263, June 1964.

To obtain relief from stress and fatigue, one can run and fight. Since this is generally impossible, tension is developed to burn up the extra blood sugar produced. Since this does occur, a midnorningand midafternoon replenishment of the blood sugar would serve to reduce fatigue.

Selye, Hans, Dr., "The Stress of Life-New Focal Point for Understanding Accidents," Proceedings of the President's Conference on Occupational Safety, U. S. Dept. of Labor, Bureau of Labor Standards, Bulletin No. 263, June 1964.

The biological conditions most likely creating accident proneness are stress and aging.

The stress syndrome, a general adaptation syndrome of three stages, begins with an alarm reaction, the mobilization of defensive forces. The next stage is that of resistance and full adaptation to the stressor; this is followed by an exhaustion stage.

The potential dangers to the worker that are caused or influenced by this stress factor are triggered by his resultant unusual fatigue, mental preoccupation, emotional disturbance and/or physical disorders.

Part 5

ACCIDENT PREDICTION AND PREVENTION

Almost every company, safety director, and university engaged in accident research has a method of reducing and preventing accidents. Many of these have been proven effective at that company for a given period of time. Since little study for general usage has been done (only specific departments or companies), it is difficult to generalize from the department to the general industrial scene.

Prevention methods have included human engineering, safety procedures, and guarding as ways of protecting the individual from machinery, thereby eliminating and preventing many accidents. Other methods have sought to screen out accident repeaters; and still others rely on posters and campaigns to introduce safety into the environment.

However none of these methods has been tested further than one or two similar companies, nor has a longitudinal study over a significant time period been conducted to verify the merits of any of these methods.

Daschbach, J. M., Jr., Ph.D., "The Development of a Procedural Analysis for Quantifying Safety Hazards Encountered in Non-Repetitive, Extended Time Work Cycles", Oklahoma State University, 1966

The study of safety normally concentrates on the accident and the results accruing from the accident. This study modifies this normal attitude to concentrate on the frequency of safety hazards which may or may not result in accidents.

Photographic evidence of safety hazard type and frequency occurrence is of great value in eliminating subjectivity in an evaluation. The development of a graphic system for safety hazard frequency recording gives direction and guidance to a safety program. Quantifying the safety hazard occurrence gives access to statistical techniques by which comparison of data is then possible. The frequency of accidents is low compared to the frequency of safety hazards in a time period. The study of safety hazards gives a better means to evaluate safety effectiveness than waiting for accident trends.

Germain & Bird, "New Horizons in Accident Prevention and Cost Improvement", American Management Association, New York, 1966, 196 pp

The prevention of disabling injuries must include the prevention of property loss accidents since an accident involving property damage is a potentially injurious accident.

In a study at Lukens Steel, the author found that the injury ratio was not as Heinrich had postulated, 1:29:300 (disabling injury: minor injury: property damage accident), but this ratio was 1:100:500 for the year 1959, a typical year.

Heath, E. D. Ph.D. "Tests and Measurement as Applied to Accident Prevention Situations." American Society of Safety Engineers Journal. Technical Section, Vol. VIII, No. 9, 11., Sept-Nov 1963, 14p.

This paper is designed to serve as a comprehensive source of information on tests, scales and other appraisal devices which have been reported in the literature as having been used to separate good risks from poor ones, or for assessing knowledge, skills, and attitudes and other personality traits believed to be related to safe performance. The devices discussed and references cited are limited to the following: 1) psycho-physical measurement including tests of skill, 2) psychological evaluation, 3) psychosocial evaluation, and 4) gross evaluation measures of the types used in audits and surveys of facilities and safety programs.

Sources of tests and evaluation measures are provided, as is a bibliography, for the individual who chooses to pursue this subject further.

Johnstone, K. T., <u>General Motors Corporation</u>, Saginaw, Michigan, "A Logical Approach to Injury Reduction", (1962) 20p.

This paper deals with a procedure of injury investigation which identifies the job factors and the individual man that are associated with the occurrence of injuries.

An individual's work injury records are filled together under his name, when four injury records have accumulated, the dates of the first and fourth are noted and the time lapsed in working days is obtained by reference to the calendar. The man's injury rate is compared to the department's injury rate. If the individual's rate is under the department's rate, he does not receive a safety interview. If the individual's injury rate is over the department's rate he is given a safety interview. The foreman inquires what is the cause of the injuries to determine if a job hazard exists. Then the employee's job attitude is assessed, is he the right man for the job. From this interview, existing job hazards are connected. Should the man be unsuited for the job, he is reassigned. Since instituting this program, General Motors Saginaw Malleable Iron Plant's overall injury rate has declined from 3.90 per 1000 man hours in 1954 to 1.11 in 1961.

Jones, D. F., Human Factors--Occupational Safety", <u>Ontario Department of Labour, Labour Safety Council of Ontario</u>, Ontario, Canada, pg. 72, 1969.

The organized safety movement and some assumptions on which it is based are examined.

Criteria for measurement of success or failure are reviewed and an attempt is made to show how these criteria must be considered to be dependent upon one another rather than as separate entities.

The prevention or avoidance of accidents is shown as a complex interaction of forces rather than the simple elimination of "unsafe acts" and "unsafe conditions".

Questions are raised as to the validity of generally accepted practices in the safety movement and stress is placed on the need for greater involvement of Human Factors Engineers and Behavioural scientists.

King, B. G., "Some Comments on Accident Prevention Research", <u>Traffic Safety Research Review</u>, Vol. 7, No. 2, pg. 19-22, June 1963.

Four basic types of human factors aspects of safety research are identified. (1) Descriptive epidemiology, quantitative in nature, is effective in defining and outlining the extent of a problem or in evaluating the effectiveness of specific prevention measures. (2) Investigative epidemiology, qualitative in nature, is useful in identifying repeated, closely similar accident patterns. (3) Experimental studies on man, as well as on the machine and the environment, can be made on basic problems that have implications for accident prevention without reference to accident occurrence. (4) Accident investigation, the direct study of specific accident situations, by a process of gradual expansion, a "family" of manageable studies on specific accidents is developed for eventual clues to cause-and-effect in a broad system. Two specific problem areas for accident research are discussed: the study of the national philosophy of safety; and the development of scientific methods of communicating safety messages.

Leininger, W. J., et. al., "Development of a Cost-Effectiveness System for Evaluating Accident Countermeasures. Volume I: Technical Report", pg. 263, National Highway Safety Bureau, Dec., 1968.

The principle product of this project is the development of an implementable cost/effectiveness evaluation system that is suitable for management use at the level of operating services and compatible with other operating systems.

Month Labor Review, "Peak Hours of California Industrial Injuries", 69:136-7, Aug. 1949.

This study was conducted on various industries during the July-August 1948 months (daylight savings time was in effect).

Peak accident rates for disabling injuries occurred at 10 to 12 AM for the morning hours and 2-4PM for the afternoon hours.

Occupation Hazards, "Do the Figures Lie?",pg. 44-46. Sept. 1969.

How honest are safety statistics? A survey of 600 safety directors indicated that while 94% keep Z16.1 statistics, and most think them adequate, many doubt their accuracy, and few think management correctly evaluates the significance of accident frequency and severity statistics. Safety directors were prolific when asked for examples of cheating. The contagion of cheating was summed up by one safety director when he wrote, "records are made to be improved, so that once cheating starts, it must continue..." Along with the problem of distorted figures for the frequency rate of accidents, three out of every four safety directors felt their top management did not understand the semantics of the Z16.1 figures and failed to put them in the proper perspective. They were thought to either overrate, underrate, or ignore the statistics. Although there were frequent criticisms of Z16.1, the majority endorsed it with some reservations and indications are that it will remain the formula for measuring accident frequency and severity for years to come.

Rockwell, T. H., "Safety Performance Measurement", Journal of Industrial Engineering, Vol. X, No. 1, pg. 12-16, Jan.-Feb., 1959.

The purpose of this study was to evaluate the use of an active sampling method to estimate the extent of unsafe behavior on a plant-wide basis. Determination of an unsafe act was a violation of company safety regulation or behavior specifically prohibited in this work.

Eight assemblers, employed at this work for four years were selected for observation from a catwalk above the job site. The observation showed that routine plant safety inspections had a sharp influence on safety behavior. Though none of the 8 assemblers had ever had a lost-time accident, the top three of the 8 workers in terms of unsafe acts accounted for 60 percent of the total first aid cases of the group.

The combined production rankings were compared to the ranking of workers with respect to average percent of unsafe acts. Despite limitations in sample size the data strongly suggest that for this particular department some risk may be required for workers to be maximally productive.

A third analysis of unsafe acts and time off the job (not absenteeism) was made. The resulting correlation shows some positive relation between the two within the limits of the sample size.

The author contends that this method of measuring safety performance has many research possibilities and can yield valuable data that can be used to evaluate, construct and modify safety programs.

Surry, J., "Industrial Accident Research. A Human Engineering Appraisal", Labour Safety Council, Ontario Department of Labour, Ontario, Canada, Pg. 242, 1968.

The aim of the report was to provide accurate and useful information to personnel in the industrial safety field about human factors in accidents. About 2000 reports on industrial safety over the past 60 years were inspected. The field's important hypotheses and experimental verifications are critically discussed and are compared, interpreted and extended with pertinent results of human engineering.

The study is first oriented by a discussion of common techniques of collecting and interpreting data, by a scientific definition of terminology, and by the development of a model which provides understanding of the multiplicity of human factors in the development of any accidental event. The heart of the report is the presentation of known and suspected relationships between human factors and accidents. The human factor are divided into personal factors (ie. biographical, physiological and psychological features), environmental factors (ie. the influence of certain environmental conditions on humans), and machine factors (i.e.

the design of machines for the use and protection of man). The report closes with a discussion of standard and proposed institutional countermeasures to accidents: the effectiveness of propaganda, selection, training, and industrial design are discussed; and 34 projects are listed which could provide more definitive knowledge for the development of institutional countermeasures. A critique of the accident proneness concept is made in an appendix.

Waldeck, T. A./McMurdo, R. B., "System Safety Engineering Analysis Techniques", Boeing Company, Seattle, Washington, pg. 185, 1966.

The "fly-fail-fix" philosophy for the development of safety became an untenable proposition for complex aerospace systems. Since safety is only one of the design parameters that influence a systems capability within the resources and time available for development, it became necessary to express safety qualitatively and quantitatively such that trade studies with other design paramenters could be made. This would allow for the greatest safety for the resources available consistent with the system objectives. A method of accomplishing the above has been applied at the Boeing Company on several programs. This document was prepared as a handbook to formalize the methods for applying this technique to any program and to make available to industry the "state of the art" in system safety engineering as we apply it.

A five point technique has been applied successfully with some modifications on all Boeing aerospace hardware and study programs since 1965. The technique results in a complete and documented safety analysis of system design with recorded safety decisions and their justification. The authors believe safer systems are achieved for the resources expended and the remaining hazards and their associated risks are known and accepted.

Wilson, D. G./Moore, J., "Transportation Resource Allocation Based on New Methods of Accident Reporting", Massachusetts Institute of Technology, Cambridge, Massachusetts, Department of Mechanical Engineering., pg. 64, Aug. 1969.

A method of allocating resources among competing transportation projects is designed to gather the varying optimum "mix" of projects as expendable transportation funds are changed. The computer program developed is based on hypothetical data obtained from a new method of accident reporting in which investigators make value judgments about the avoidable costs of each causative factor present in the accident situation. A suggested accident-reporting form, and some details of the hardware which would enable the form to be filled out at the scene of an accident, are given.

Winograd, B., "Army Accident Reporting Results of Some Exploratory Interviews", Department of the Army, Washington, D. C., pg. 37, Sept. 15, 1966.

The Safety Branch of the Department of the Army undertook a systematic investigation of their accident reporting system to the following questions:

How accurate and complete is accident reporting?
What kinds of inaccuracies occur and with what frequencies?
What are the causes of these inaccuracies?

The interview was the technique used to obtain information in this investigation.

The interviews with safety directors revealed some of their attitudes and opinions about accident reporting, and the main findings are:

Reporting completeness, quality and intensiveness depend on the seriousness of the accident and on the type of installation at which it is reported. In general, serious accidents are reported more completely than trivial accidents. The reporting systems of installations with a preponderance of civilian personnel produce more record-keeping and more intensive reporting than posts with a preponderance of military.

The usefullness of reports is adversely affected by motivations of supervisors that are contrary to the interests of accurate reporting. These motivations include the supervisor's desire to protect his men from punishment and to protect his safety record from any blemish.

Safety directors are under indirect pressures from military commanders to under-enumerate accidents.

Predictive Models

Air Force Department, Missile Safety Division, "An Acceptable Individual Risk Criterion". Norton Air Force Base, California. 1968, 23 pp.

Arguments for an acceptable individual risk criterion, to be applied against any particular hazardous operation, are developed. A "one-in-a-million (0,000,001) fatality probability is selected as one which is in consonance with those normal hazards experienced in routine, day to day living, the recommendation is made for Air Force adaption of a 0,000,001 individual risk criterion for guidance in the application of safety programs.

Canale, S., "System Safety Measurement and Control". Annuals of Reliability and Maintainability, Vol. 5, 19 July 1966, 8 pp.

This paper presents a new technical definition of safety and a method of measuring (predicting) the safety level of a system. The application of the definition provides a method which is applied to a relatively simple hypothetical system having several types of potential hazards.

The measurement procedure used to obtain the safety level of the system involves several steps leading to the calculation of (1) probability of control of these hazards, (2) magnitude of the hazards, and (3) cost of controls. For comparison purposes, calculations are made for the hypothetical system with and without significant application of safety effort. These calculations provide data needed for Cost Effectiveness analyses. System Effectiveness is shown as a function of the safety level of the system.

The overall procedure for safety measurement appears to be feasible and sound since it is based primarily on technical characteristics of physical systems. However, limitations, similar to limitations on any measurement process of related disciplines, exist at the present time. A recommendation to use this procedure to promote future military and industrial progress is given.

Grimaldi, J. V., "Appraising Safety Effectiveness". SAE Journal, p. 57-62.

Nine principal cost items, typical of manufacturing operations, were studied statistically relative to measures associated with safety performance. The data were taken from 17 varied businesses over a three year period.

It was indicated that in operating components where there is a fairly good control of all contingency costs, a generally good safety profile prevails.

Difference in safety performance appears to be indicated by differences in severity rates and average severity, rather than the generally accepted frequency rate.

It appears possible to compute, from cost accounting data, a measure which indicates management effectiveness in controlling contingency costs and predicts safety experience.

Jacobs, Herbert H., "Mathematical Models Applied to Accident Processes", Dunlap and Associates, Inc.

An assumption is made that, if the phenomenon of contagion does occur in human accident behavior, it occurs along with, rather than instead of, individual differences in accident liability. An appropriate accident behavior model, than, should include both effects. However, the available accident distribution models do not permit the simultaneous estimation of these two effects.

This model combines all of the effects of interest in accident models, namely, contagion, time, and population structure. This is because the author has good reason to expect that they will occur together rather than alternatively and shall want to estimate the three effects simultaneously.

Kanda, K., "The Expansion of the System Safety Analysis in the Realm of Probability", Boeing Company, Missile and Information Systems Division, Seattle, Washington, 1967, 50 p.

System safety can use the probability tool as a method of measuring comparative safety between designs. Probabilities can be used with an analytical mathematical model to depict undesirable events. One such mathematical modeling method is the system safety fault tree.

A system safety fault tree of an actual city intersection is shown in this paper as an illustration of how system safety fault tree methods can be used to design and prevent undesirable traffic events. Where there is a high rate of undesirable events (accidents and fatalities), data can be gathered by actual observations under the actual environmental conditions of the intersection, such as entering the intersection on amber and red lights. This data is then manipulated into probabilities for these events. Such probabilities are placed into a mathematical model, such as the system safety fault tree. The outcome of the system safety fault tree analysis can be used to estimate undesirable events. The retention of the data is used to incorporate preventive measures to diminish further undesirable events. Hence a system safety sequence of investigation or data gathering, mathematical or physical analysis, correction, re-evaluation, retention of data is desirable.

Knowles, Wm. B., and Burger, Wm. J., and others, "Models, Measures, and Judgments in System Design", Human Factors, 1969, 11(6), 577-590.

This paper assumes increasing use of analytical models in system design. Some characteristics of such models and requirements for human performance data compatible with them are discussed. Methods of obtaining human performance measures is reviewed. Two new studies are reported in support of the proposition that expert judgments may offer a practical method of obtaining performance measure with potentially wide application in analytical modeling efforts.

Maguire, B. A., Pearson, E. S., and Wynn, A. H. A., "The Time Intervals Between Industrial Accidents", Biometrika, XXXIX (1952), 168-180.

An analysis fo the time intervals between accidents may provide earlier indication of improvement of the number of accidents, than analysis of the accident frequency.

Modern Materials Handling, "Air Force Seminar Zeroes-In on Human Error in Materials Handling", 18:7, March 1963, pp. 7.

Materials handling equipment accidents are largely due to human error, in fact, approximately 87 percent are in this category at Norton Air Force Base.

To alleviate this, the same kind of analysis and recommendation for remedial action that results from studies of materiel fail-

ures was used. The procedure for this resulted in dividing human error accidents into three categories: willful negligence or violation, inexperience and, situations demanding more of the man than he can handle at the time.

Rees, A. G., "Safety Sampling. A Technique for Measuring Accident Potential". British Journal of Occupational Safety, Vol. 7, No. 79. Abstract taken from Excerptamedica, Vol, 13, No. 10 October 1967, pp. 827.

The author describes a method of measuring the accident potential of a factory by counting the number of unsafe acts or conditions that can be seen along a given route in a given time. If such a procedure is repeated on a weekly basis, a guide is given to the improvement or deterioration in accident potential. The information gained is passed to the manager of each department for action, and charts are prepared for display in the works. The proper selection and training of persons making the survey is important and the author describes his method of training members of line management to become competent observers.

Regulinski, T. L., and Askren, Wm. B., "Mathematical Modeling of Human Performance Reliability", Proceedings of the 1969 Annual Symposium on Reliability, Chicago, Illinois, Jan. 21-23, 1969.

The prelimianry results of research are presented, aimed at the feasibility of mathematically modeling human performance reliability. The study addressed itself to time continuous tasks with the derivation of a general mathematical model of the probability of errorless performance which is equated to human performance reliability. The application of this model and the implications of the time to first error concept were tested with a laboratory experiment using a vigilance task.

Teel, K. S., and DuBois, P. H., "Psychological Research on Accidents: Some Methodological Considerations", Journal of Applied Psychology, 1954, 38, 397-400.

The author discusses the problems of accident data and the statistical techniques associated with them; accident proneness is usually indicated by variations of the obtained distribution from the Poisson, but, this could merely reflect differences in risk exposure. Another point is made when the obtained distribution is the same as the Poisson, there may still be significant correlations between accident records in successive periods or between accident records and logically related predictors.

The authors suggest more sensitive criterion measures that would include "near accidents", and better differentiation between "personal" and "situational" accidents.

APPENDIX D

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APPENDIX E

Below are listed the sources used in the Industrial Accident Data Survey. The sources used in gathering the names of these organizations are listed in the introduction to Appendix B.

Aerospace Technology Division
First St. & Independence Avenue S.E.
Washington, D.C. 20540

AEROJET-GENERAL CORPORATION
Von Karman Center
Azusa, California 91702

Atomic Energy Commission
Main Office at Germantown, Md.
Mailing Address: Washington, D.C. 20545

American Association of Industrial Dentists,
Office of the Secretary
14 Hunter Lane
Camp Hill, Pennsylvania 17011

American Chemical Society
1155 16th Street N.W.
Washington, D.C. 20036

American College of Surgeons
40 East Erie Street
Chicago, Illinois 60611

American Conference of Governmental Industrial Hygienists
1014 Broadway
Cincinnati, Ohio 45202

American Industrial Hygiene Association
25711 Southfield Road
Southfield, Michigan 48075

American Society for Industrial Security
2000 K Street N.W.
Washington, D.C. 20006

American Public Health Association
1740 Broadway
New York, New York 10019

American Society of Mechanical Engineers
345 East 47th Street
New York, New York 10017

Alpha Chi Sigma
5503 E. Washington Street
Indianapolis, Indiana 46219

American Medical Association
535 North Dearborn Street

Chicago, Illinois 60610

American Nurses' Association, Inc.
10 Columbus Circle
New York, New York 10019

American Gas Association
605 Third Avenue
New York, New York 10016

Air Line Pilots Association
Engineering and Safety Division
55th Street & Cicero Avenue
Chicago, Illinois 60638

Aerospace Materials Information Center (AMIC)
Air Force Materials Laboratory (MAAM)
Wright-Patterson Air Force Base, Ohio 45433

Aerospace Safety Research and Data Institute
NASA-Lewis Research Center
21000 Brook Park Road
Cleveland, Ohio 44135

American Institute of Aeronautics & Astronautics (AIAA)
750 Thrid Avenue
New York, New York 10017

American National Red Cross Safety Services
17th and "D" Streets N.W.
Washington, D.C. 20006

Aeronautical Research Institute of Sweden
Stockholm, Sweden

American Standards Institute
1430 Broadway
New York, New York 10018

American Society of Safety Engineers
850 Busse Highway
Park Ridge, Illinois 60068

American Society for Testing & Materials
1916 Race Street
Philadelphia, Pennsylvania 19103

American Welding Society
345 East 47th Street
New York, New York 10017

Associated General Contractors of America, Inc.
1957 East Street N.W.
Washington, D.C. 20006

The American Association of State Compensation
Insurance Funds
P.O. Box 5922
San Francisco, California 94101

American Mutual Insurance Alliance
20 North Wacker Drive
Chicago, Illinois 60606

American Insurance Association
Engineering and Safety Department
85 John Street
New York, New York 10038

American Association of Oilwell Drilling Contractors
211 North Ervay Bldg., Suite 505
Dallas, Texas 75201

Association of American Railroads
1920 L Street N.W.
Washington, D.C. 20006

American Road Builders Association
525 School Street S.W.
Washington, D.C. 20024

American Petroleum Institute
Safety & Fire Protection Services
1271 Avenue of the Americas
New York, New York 10020

American Water Works Association
2 Park Avenue
New York, New York 10016

The American Waterways Operators, Inc.
1250 Connecticut Ave. N.W., Suite 502
Washington, D.C. 20036

American Paper Institute
260 Madison Avenue
New York, New York 10016

American Mining Congress
1102 Ring Bldg.
Washington, D.C. 20036

American Meat Institute
59 East Van Buren Street
Chicago, Illinois 60605

American Pulpwood Association
605 Third Avenue
New York, New York 10016

American Trucking Associations, Inc.
1616 P Street N.W.
Washington, D.C. 20036

American Foundrymen's Society
Golf and Wolf Roads
Des Plaines, Illinois 60016

State Board of Workmen's Compensation
494 Labor Building
254 Washington Street S.W.
Atlanta, Georgia 30334

Bendix Corporation
Aerospace Division
717 North Bendix Drive
South Bend, Indiana 46620

Bureau of Labor Statistics
Box T, Capitol Station
Austin, Texas 78711

Bureau of Labor Statistics
Box T, Capitol Station
Austin, Texas 78711
ATTN: Safety Division

British Columbia Lumber Manufacturers Assoc.
(Safety Director)
302 Forest Industries
Building 550 Burrard Street
Vancouver, British Columbia
Canada

Bureau of Employees' Compensation
Vanguard Building
Washington, D.C. 20211

Bureau of Labor
115 Labor and Industries Bldg.
Salem, Oregon 97310

Burea of Labor

Office & Laboratory Bldg.
East Seventh & Court Aves.
Des Moines, Iowa 50319
ATTN: Safety Division

The Boeing Company
P.O. Box 3707
Seattle, Washington 98124

Bureau of Workmen's Compensation
Ohio Department Bldg.
Columbus, Ohio 43215

British Columbia Loggers' Association (Manager)
550 Burrard Street
Vancouver, British Columbia
Canada

Bituminous Coal Operators' Association
918 16th Street N.W.
Washington, D.C. 20006

Cornell Aeronautical Laboratory, Inc.
Box 235
Buffalo, New York 14221

Cryogenic Data Center
National Bureau of Standards
Institute for Materials Research
Boulder, Colorado 80301

Chemical Propulsion Information Agency (CPIA)
Applied Physics Laboratory
The Johns Hopkins University
8621 Georgia Avenue
Silver Spring, Maryland 20910

Can Manufacturers Institute, Inc.
821 15th Street
Washington, D.C. 20005

Compressed Gas Association, Inc.
500 Fifth Ave.
New York, New York 10036

Coal Mine Inspection Department (Chief Inspector)
1525 Sherman Street
Denver, Colorado 80203

The Chlorine Institute
342 Madison Avenue

New York, New York 10017

Chief Factory Inspector
411 Dunsmuir Street
Vancouver 3, British Columbia
Canada

Canada Department of Labour
Accident Prevention and Compensation Branch
340 Laurier Avenue West
Ottawa, Ontario
Canada

Defense Research Medical Laboratories
P.O. Box 62, Postal Station K
Toronot, Ontario
Canada

Department of Labour (Minister)
Unemployment Insurance Commission Bldg.
10210-107 Street
Edmonton, Alberta
Canada

Department of Labour (Minister)
1011 W. Pender Street
Victoria, British Columbia
Canada

Department of Labor and Industrial Relations
506 W. Tenth Street
Wilmingt n, Delaware 19801

Department of Labour (Minister)
Mall Centre Bldq.
491 Portage Ave.
Winnipeg, Manitoba
Canada

Division of Occupational Health & Factory Inspection
2423 N. State Street
Jackson, Mississippi 39205

Department of Labor and Industrial Relations
1604 W. Dunklin
Jefferson City, Missouri 65101

Division of Workmen's Compensation
1604 W. Dunklin
P.O. Box 58
Jefferson City, Missouri 65101

Department of Labor & Industry
Mitchell Building
Helena, Montana 59801
ATTN: Industrial Accident Board

Department of Labor & Industry
Mitchell Bldg.
Helena, Montana 59801
ATTN: Division of Safety

Department of Labor
State Capitol
Lincoln, Nebraska 68509
ATTN: Division of Safety

Department of Labor
235 Promenade Street
Providence, Rhode Island 02908
ATTN: Workmen's Compensation Division

Department of Labor
Rutledge Building
1429 Senate Street
P.O. Box 11329
Columbia, South Carolina 29211
ATTN: Division of Safety

Department of Labor & Industry
301 West Preston Street
Baltimore, Maryland 21201
ATTN: Division of Industrial Safety

Department of Labor & Industry
301 West Preston Street
Baltimore, Maryland 21201
ATTN: Division of Safety Inspection

Department of Labor & Industries
State Office Building
Government Center
100 Cambridge Street
Boston, Massachusetts 02202
ATTN: Division of Industrial Accidents

Department of Public Safety
1010 Commonwealth Avenue
Boston, Massachusetts 02115

Department of Labor
300 E. Michigan Avenue

Lansing, Michigan 48913
ATTN: Workmen's Compensation Dept.

Department of Labor
300 E. Michigan Avenue
Lansing, Michigan 48913
ATTN: Bureau of Safety and Regulation

Department of Labor
Cordell Hull Building
Nashville, Tennessee 37219
ATTN: Workmen's Compensation Division

Department of Labor
Cordell Hull Building
Nashville, Tennessee 37219
ATTN: Construction Safety

Department of Labor and Industry
110 State Office Bldg.
St. Paul, Minnesota 55101
ATTN: Division of Accident Prevention

Department of Labor & Industry
Labor and Industry Building
Harrisburg, Pennsylvania 17120

Department of Labor and Industry
110 State Office Bldg.
St. Paul, Minnesota 55101
ATTN: Workmen's Compensation Commission

Department of Labor
401 Topeka Avenue
Topeka, Kansas 66603
ATTN: Industrial Safety

Department of Labour (Minister)
Federal Building
633 Queen Street
Fredericton, New Brunswick
Canada

Department of Health, Education, and Welfare
330 Independence Ave. S.W.
Washington, D.C. 20201

Department of Labor
P.O. Box 1151
Raleigh, North Carolina 27602

Department of Transportation
National Transportation Safety Board
Bureau of Aviation Safety
Washington, D.C. 20591

Department of Labor
State Capitol
Bismarck, North Dakota 58501

Department of Industrial Relations
220 Parsons Avenue
Columbus, Ohio 43215
ATTN: Division of Factory and Building Inspection

Department of Labor and Industry
Montpelier, Vermont 05602

Department of Labor (Commissioner)
624 West Seventh Street
Little Rock, Arkansas 72201

Department of Transportation
Federal Aviation Agency (FAA)
800 Independence Avenue, S.W.
Washington, D.C. 20590

Department of Transportation
Safety Board (NTSB)
Bureau of Aviation Safety
Washington, D.C. 20591

Department of Labor and Industries
General Administration Building
Olympia, Washington 98501
ATTN: Safety Division

Department of Labor
643 State Office Building
Charleston, West Virginia 25305
ATTN: Division of Safety

Department of Labor and Personnel
P.O. Box 884
Agana, Guam 96910

Department of Labor and Industrial Relations
825 Mililani Street
Honolulu, Hawaii 96813
ATTN: Workman's Compensation Division

Department of Labor

State Office Bldg. Annex
Frankfort, Kentucky 40601
ATTN: Workmen's Compensation Board

Department of Labor
State Office Bldg. Annex
Frankfort, Kentucky 40601
ATTN: Industrial Safety Board

Department of Labor
205 Capitol Annex
P.O. Box 44063
Baton Rouge, Louisiana 70804
ATTN: Division of Occupational Safety & Health

Department of Labor
205 Captiol Annex
P.O. Box 44063
Baton Rouge, Louisiana 70804
ATTN: Workmen's Compensation

Department of Labor & Industry
State Office Bldg.
Augusta, Maine 04330
ATTN: Division of Industrial Safety

Department of Industry, Labor and Human Relations
Hill Farms State Office Building
P.O. Box 2209
Madison, Wisconsin 53701

Department of Industry, Labor & Human Relations
Hill Farms State Office Building
P.O. Box 2209
Madison, Wisconsin 53701
ATTN: Industrial Safety & Building Division

Department of Industry, Labor & Human Relations
Hill Farms State Office Building
P.O. Box 2209
Madison, Wisconsin 53701
ATTN: Division of Labor Standards

Department of Industry, Labor & Human Relations
Hill Farms State Office Bldg.
P.O. Box 2209
Madison, Wisconsin 53701
ATTN: Workmen's Compensation Dept.

Department of Labor & Statistics
304 Capitol Bldg.

Cheyenne, Wyoming 82001

Department of Labor and Industrial Relations
825 Mililani Street
Honolulu, Hawaii 96813
ATTN: Industrial Safety Division

Department of Labor
State Capitol
Oklahoma City, Oklahoma 73105

Department of Labor
111 W. Telegraph Street
Carson City, Nevada 89701
ATTN: Department of Industrial Safety

Department of Labor
State House Annex
Concord, New Hampshire 03301
ATTN: Workmen's Compensation Division

Department of Labor and Industry
John Fitch Plaza
P.O. Vox V
Trenton, New Jersey 08625
ATTN: Division of Labor, Bureau of Engineering & Safety

Department of Labor & Industry
John Fitch Plaza
P.O. Box W
Trenton, New Jersey 08625
ATTN: Division of Workmen's Compensation

Labor & Industrial Commission
137 E. DeVargas Street
Santa Fe, New Mexico 87501

Department of Labor
State Campus
Albany, New York 12226

Division of Industrial Safety Service
80 Centre Street
New York, New York 10013

Department of Labor and Industry
P.O. Box 1814
State Office Building
Richmond, Virginia 23219

Department of Labor and Industry

P.O. Box 1810
State Office Building
Richmond, Virginia 23219
ATTN: Division of Industrial Safety

Department of Labor
P.O. Box 708
Christiansted, St. Croix
Virgin Island 00801

Department of Labor
Division of Workmen's Compensation
St. Thomas, Virgin Islands 00801

Division of Industrial Hygiene
80 Centre Street
New York, New York 10013

Department of Labor
Industrial Administration Bldg.
317 Main Street
Boise, Idaho 83702
ATTN: Industrial Accident Board

Department of Labor
State Labor Building
Atlanta, Georgia 30334

Douglas Aircraft Company
3000 Ocean Park Boulevard
Santa Monica, California 90406

Department of Industrial Relations (Director)
455 Golden Gate Avenue
P.O. Box 603
San Francisco, California 94101

Division of Labor
Indidna State Office Building
Room 1013
100 N. Senate Avenue
Indianapolis, Indiana 46204

Defense Ceramic Information Center (DCIC)
Battelle Memorial Institute
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Defense Metals Information Center (DMIC)
Battelle Memorial Institute

Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Department of Labor
160 N. LaSalle Street
Chicago, Illinois 60601

Department of Interior
Bureau of Mines
18th and C Streets, N.W.
Washington, D.C. 20240

Department of Labor
14th Street and Constitution Ave. N.W.
Washington, D.C. 20210

Department of Transportation
800 Independence Ave. S.W.
Washington, D.C. 20590

Department of Labour (Minister)
Sir Humphery Gilbert Blvd.
Duckworth Street
St. John's, Newfoundland
Canada

Department of Labour (Minister)
Sir John Thompson Bldg.
1256 Barrington Street
Halifax, Nova Scotia
Canada

Department of Labour (Minister)
Arcade Bldg.
74 Victoria Street
Toronto, Ontario
Canada

Department of Industrial Relations (Director)
Industrial Relations Building
Montgomery, Alabama 36104

Department of Labor (Commissioner)
P.O. Box 1149
Juneau, Alaska 99801

Department of Labour (Minister)
Postal Station "B" Building
685 Cathcart Street
Montreal, Quebec

Canada

Department of Labour (Minister)
Government Telephone Bldg.
2350 Albert Strett
Regina, Saskatchewan
Canada

Environmental Control Administration
12720 Twinbrook Parkway
Rockville, Maryland 20852

Electronic Properties Information Center (EPIC)
Air Force Materials Laboratory (MAAM)
Wright-Patterson AFB, Ohio 45433

Edison Electric Institute
750 Third Avenue
New York, New York 10017

Food and Drug Administration
Crystal Plaza
Building 5
2211 Jefferson Davis Parkway
Arlington, Virginia 22202

Flight Safety Foundation
468 Fourth Avenue
New York, New York 10016

Factory Insurance Association
85 Woodland Street
Hartford, Connecticut 06105

Factory Mutual Engineering Corporation of the
Factory Mutuual System
1151 Boston-Providence Turnpike
Norwood, Massachusetts 02062

Federal Safety Council
Room 407
Railway Labor Building
First and D Streets N.W.
Washington, D.C. 20210

Federal Highway Administration
Sixth and D Streets S.W.
Washington, D.C. 20591

Federal Railroad Administration
Sixth and D Streets S.W.

Washington, D.C. 20591

General Dynamics - Astronautics
Box 1128
San Diego, California 92112

Grumman Aircraft Engineering Corporation
System Safety, Engineering Dept.
Plant #35
Bethpage, Long Island, New York 11714

Government Pulbications
Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

George Washington University
School of Engineering and Applied Science
Washington, D.C.

Gray and Ductile Iron Founders' Society, Inc.
930 National City
East Sixth Bldg.
Cleveland, Ohio 44114

Daniel and Florence Guggenheim
Aviation Safety Center
2038 1/2 Griffith Park Boulevard
Los Angeles, California 90052

Guggenheim Aviation Safety Center at Cornell University
c/o R. M. Woodham
181 Pasadena Place
Hawthorne, New Jersey 07506

Daniel & Florence Guggenheim
Center for Aerospace Health & Safety
Harvard School of Public Health
665 Huntington Avenue
Boston, Massachusetts 02115

Health Physics Society
194 Pilgrim Road
Boston, Massachusetts 02215

Health Services and Mental Health Administration
330 C Street S.W.
Washington, D.C. 20201

Industrial Accident Board
State Insurance Building

Austin, Texas 78714

Industrial Safety Division
Department of Labor and Industry
Montpelier, Vermont 05602

Industrial Commission
438 State Capitol
Salt Lake City, Utah 84114

Industrial Commission
Administer of Workmen's Compensation
1429 Senate Street
Columbia, South Carolina 29201

International Civil Aviation Organization
International Aviation Building
1080 University Street
Montreal 3, Quebec
Canada

International Federation of Airline Pilots Associations
One Hyde Park Place
London, W. 2, England

Industrial Commission
Pierre, South Dakota 57501
ATTN: Division of Labor

Industrial Commission
Education Building
Raleigh, North Carolina 27602
ATTN: Safety Director

Industrial Commission
Caldwell Building
Tallahassee, Florida 32304

Industrial Accident Board
Administers Workmen's Compensation
Odd Fellows Bldg.
Wilmington, Delaware 19801
ATTN: Division of Safety Inspection

Industrial Accident Commission
State Office Building
Augusta, Maine 04330

Industrial Hygiene Foundation of America
5231 Centre Avenue
Pittsburgh, Pennsylvania 15232

Illuminating Engineering Society
345 East 47th Street
New York, New York 10017

Industrial Commission (Chairman)
Administers Workmen's Compensation
State Capitol Annex
East 14th Avenue and Sherman Street
Denver, Colorado 80203

Industrial Medical Association
55 East Washington Street
Chicago, Illinois 60602

Institute of Makers of Explosives
420 Lexington Avenue
New York, New York 10017

Industrial Commission
Blanton Building
P.O. Box 1794
Richmond, Virginia 23214
ATTN: Department of Workmen's Compensation

Industrial Safety Equipment Association, Inc.
60 East 42nd Street
New York, New York 10017

Industrial Commission
Administers Workmen's Compensation
160 N. LaSalle Street
Chicago, Illinois 60601

Industrial Board
Administers Workmen's Compensation
State Office Building
Room 601
Indianapolis, Indiana 46204

Industrial Commission (Chairman)
Administers Workmen's Compensation
1616 W. Adams Street
Phoenix, Arizona 85007

International Acetylene Association
% Compressed Gas Association, Inc.
500 Fifth Avenue
New York, New York 10036

International Association of Governmental Labor Officials

401 Railway Labor Building
First and D Streets N.W.
Washington, D.C. 20001

International Association of Industrial Accident
Boards and Commissions
Office of Secretary-Treasurer
Bureau of Labor Standards
U.S. Department of Labor
Washington, D.C. 20210

International Labor Organization
Labor Office
U.S.A. Branch
917 15th Street N.W.
Washington, D.C. 20005

Johns Hopkins University
8621 Georgia Avenue
Silver Spring, Maryland 20910

Lockheed-Georgia Company
Manager, System Safety
86 South Cobb Drive
Marietta, Georgia 30061

Library of Congress
First Street and Independence Avenue S.E.
Washington, D.C. 20540

Labor Department (Commissioner)
200 Folly Brook Blvd.
Hartford, Connecticut 06115

The Lumberman's Accident Prevention Association, Inc.
(President, Secretary-Manager)
65 St. Anne Street
Quebec, Canada

Miller's Accident Prevention Association
Flour Mill
Saskatchewan, Canada

Martin Company
System Safety Engineering
P.O. Box 179
Denver, Colorado 80201

Minimum Wage and Industrial Safety Board
601 Indiana Avenue N.W.
Washington, D.C. 20004

Mine Inspection Department
St. Mine Inspector
505 First National Bank Building
Fort Smith, Arkansas 72901

Manufacturing Chemists' Association, Inc.
1825 Connecticut Ave. N.W.
Washington, D.C. 20009

Mine Inspectors' Institute of America
1900 Grant Bldg.
Pittsburgh, Pennsylvania 15219

McDonnell Aircraft Corporation
Lambert-Street Louis Municipal Airport
Box 516
St. Louis, Missouri 63166

Mines Accident Prevention Association of Ontario
Executive Director
320 Bay Street
Toronto, Ontario
Canada

Nova Scotia Accident Prevention Association
Manager
231 Hollis Street
Halifax, Nova Scotia
Canada

New Brunswick Accident Prevention Association
Secretary-Manager
P.O. Box 755
55 Canterbury Street
Saint John, New Brunswick
Canada

National Transportation Safety Board
1825 Connecticut Avenue N.W.
Washington, D.C. 20590

New York State Dept. of Labor
Division of Reserach & Statistics
80 Center Street
New York, New York 10013

National Fire Protection Association
60 Batterymarch Street
Boston, Massachusetts 02110

National Safety Council
Safety Research Information Service (SRIS)
425 No. Michigan Avenue
Chicago, Illinois 60611

National Safety Council
Aersopace Section
425 North Michigan Avenue
Chicago, Illinois 60611

National Research Council of Canada
Ottowa, Canada

National Science Foundation
1951 Constitution Avenue N.W.
Washington, D.C. 20550

North Ame ican Aviation, Inc.
Systems Safety Office
1700 East Imperial Highway
El Segundo, California 90246

Nuclear Safety Information Center (NSIC)
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, Tennessee 37831

National Society for the Prevention of
Blindness, Inc.
79 Madison Avenue
New York, New York 10016

National Petroleum Refiners Association
1725 De Sales Street N.W.
Washington, D.C. 20036

National LP-Gas Association
79 West Monroe Street
Chicago, Illinois 60603

National Association of Refrigerated Warehouses
1210 Tower Building
Washington, D.C. 20005

National Association of Manufacturers
277 Park Avenue
New York, New York 10017

National Coat Association
1130 17th Street N.W.
Washington, D.C. 20036

New York Shipping Association, Inc.
80 Broad Street
New York, New York 10004

National Rural Electric Cooperative Association
2000 Florida Avenue N.W.
Washington, D.C. 20009

New York University
Center for Safety Education
Washington Square
New York, New York 10003

Office of State Mine Inspector
State Mine Inspector
140 Capitol Building
Phoenix, Arizona 85007

Portland Cement Association
5420 Old Orchard Road
Skokie, Illinois 60078

The Quebec Pulp and Papaer Safety Association
President, Secretary-Treasurer
65 St. Anne Street
Quebec, Canada

Royal Canadian Air Force
Institute of Aviation Medicine
1107 Avenue Road
Toronto 12, Ontario
Canada

Railroad Retirement Board
844 Rush Street
Chicago, Illinois 60611

The Rand Corporation
1700 Main Street
Santa Monica, California 90466

Society of Automotive Engineers
Two Pennsylvania Plaza
New York, New York 10001

The Society of the Plastics Industry, Inc.
250 Park Avenue
New York, New York 10017

Steel Plate Fabrication Association, Inc.
19 South La Salle Street
Chicago, Illinois 60603

Steel Scaffolding and Shoring Institute
2130 Keith Building
Cleveland, Ohio 44115

State Insurance Fund
317 Main Street
P.O. Box 1038
Boise, Idaho

State Compensation Insurance Fund
General Manager
525 Golden Gate Avenue
San Francisco, California 94102

State Insurance Fund
199 Church Street
New York, New York 10007

State Industrial Court
State Capitol
Oklahoma City, Oklahoma

Technical Information and Library Services
Ministry of Aviation
Farnborough, Hants, England

Trans World Airlines, Inc.
10 Richards Road
Kansas City, Missouri 64108

Thompson Ramo Wooldridge
Space Technology Laboratories
One Space Park
Redondo Beach, California 90278

Transportation Safety Association of Ontario
Trucking Manager
90 Harbour Street
Toronto, Ontario
Canada

University of Southern California
Institute of Aerospace Safety and Management
University Park
Los Angeles, California 90007

University of Washington

Office of Short Courses and Conferences
336 Lewis Hall
Seatle, Washington 98105

Underwriters Laboratories
207 East Ohio Street
Chicago, Illinois 60611

United Aircraft Corporation
400 Main Street
East Hartford, Connecticut 06108

United Air Lines, Inc.
P.O. Box 8800
O'Hare International Airport
Chicago, Illinois 60666

United Air Lines, Inc.
San Francisco International Airport
San Francisco, California 94128

United Air Lines, Inc.
Stapleton International Airport
Denver, Colorado 80220

U. S. Air Force
Director of Aerospace Safety
Norton Air Force Base
California 92409

U. S. Army
U. S. Army Board for Aviation Accident Research
Fort Rucker, Alabama 36360

U. S. Naval Safety Center
ATTN: Safety Education Office
U. S. Naval Air Station
Norfolk, Virginia 23511

U. S. Navy
U. S. Naval Aviation Safety Center
U. S. Naval Air Station
Norfolk, Virginia 23511

United States Coast Guard
1300 E Street N.W.
Washington, D.C. 20591

Workmen's Compensation Board
Chairman
1840 Lorne Street

Regina, Saskatchewan
Canada

Workmen's Compensation Board
Minister
P.O. Box 757
Charlottetown, Prince Edward Island
Canada

Workmen's Compensation Board
Chairman
P.O. Box 1150
Halifax, Nova Scotia
Canada

Workmen's Compensation Board
Chairman
90 Harbour Street
Toronto 1, Ontario
Canada

Workmen's Compensation Board
Chairman
P.O. Box 160
St. John, New Brunswick
Canada

Workmen's Compensation Board
Chairman
707 West 37th Avenue
Vancouver 13, British Columbia
Canada

Workmen's Compensation Board
Chairman
1048-101A Avenue
Edmonton, Alberta
Canada

Workmen's Compensation Board
Chairman
333 Maryland Street
Winnipeg, Manitoba
Canada

Workmen's Compensation Commission
Chairman
Justice Building
Little Rock, Arkansas 72201

Workmen's Compensation Commission

Chairman
110 Broadway
Norwich, Connecticut 06360

Workmen's Compensation Service
State Office Building
Des Moines, Iowa 50319

Workmen's Compensation Director
State Orrice Bldg.
Room 1007N
Topeka, Kansas 66612

Workmen's Compensation Commission
Barnett Building
P.O. Box 651
Jackson, Mississippi 39205

Workmen's Compensation Court
State Capitol
Lincoln, Nebraska 68509

Workmen's Compensation Board
50 Park Place
New York, New York 10007

Workmen's Compensation Bureau
ATTN: Safety Inspector
State Capitol
Bismarck, North Dakota 58501

Workmen's Compensation Board
Labor and Industries Building
Salem, Oregon 97310

Workmen's Compensation Board
1103 Deposit Savings Bank Building
Wilkes-Barre, Pennsylvania 18701

Workmen's Compensation Fund
112 California Avenue
Charleston, West Virginia 15305

Workmen's Compensation Department
2305 Carey Avenue
P.O. Box 408
Cheyenne, Wyoming 82001

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National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California 94035

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Safety Officer
National Aeronautics and Space Administration
Flight Research Center
Post Office Box 273
Edwards, Cal. 93523

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Goddard Space Flight Center
Greenbelt, Maryland 20771

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Kennedy Space Center, Florida 32899

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Langley Station
Hampton, Virginia 23365

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21000 Brookpark Road
Cleveland, Ohio 44135

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Manager, Safety Office (SA)
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas 77058

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National Aeronautics and Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

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National Aeronautics and Space Administration
Mississippi Test Facitlity
Bay St. Louis, Mississippi 39520

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Pasadena, California 91103

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National Aeronautics and Space Administration
Nuclear Rocket Development Station
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Jackass Flats, Nevada 89023

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Safety Officer (RED/RSB)
National Aeronautics and Space Administration
Wallops Station
Wallops Island, Virginia 23337

Bill L. Grider
National Aeronautics and Space Administration
KSC Western Test Range Operations Division
Post Office Box 425
Lompoc, California 93436

L. Maurice Clelland
MSC-White Sands Test Facility
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Washington, D. C. 20546

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Washington, D. C. 20546

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